THE EFFECTS OF PROJECT-BASED LEARNING IN HIGH SCHOOL GEOMETRY

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAIʻI AT MĀNOA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF EDUCATION

IN

PROFESSIONAL EDUCATIONAL PRACTICE

AUGUST 2014

By

William Chin

Dissertation Committee:

Thanh Truc Nguyen, Chairperson

Catherine Payne

Keywords: High School, Project-Based Learning, Geometry

ABSTRACT

Project-based learning is a teaching method that supports students' concrete understanding of abstract mathematical concepts. The method engages students' interest and curiosity by allowing them to complete projects that relate to real-world situations. This method of learning requires teachers to plan and develop projects that encourage students to work individually and in groups to solve problems, plan, collaborate, make decisions, develop technology skills and present projects to their peers. Project-based learning was implemented in a high school classroom. The effectiveness of Project-based learning implementation in the high school geometry classroom was assessed and analyzed to see if technology use and hands-on experiences improved the level of students' mathematical comprehension. Students expressed a sense of satisfaction in learning mathematical concepts through the use of technology and hands-on experiences. Mathematical concepts became clearer with the use of tangible objects and technological devices.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Background

The globalization of education through technology is requiring public schools to introduce more extensive innovations and interventions that will improve student learning. To meet students' educational needs and to compete on the global market, more expectations are being put upon public schools by the federal and state governments to improve the learning environment. Thus, frequent changes and innovative ways to teach students are continually emerging. Educators generally agree that all elementary and secondary school students need to have an engaging, challenging, and rigorous public education. The teachers that work at my school comment that their students learn best, when student learning is active and challenging, such as being mentally involved, engaged in hands-on activities, in the process of inquiry and investigation, discovery, and interpretation. Currently, one particular concern of public school education is how the subject of mathematics is taught.

The content of mathematics is a major area in which many public school students continue to struggle to grasp. Traditional teacher-centered mathematics teaching methods that have negatively affected students' understanding of math is still prevalent in many mathematics classrooms. As stated by Geist and King (2008), many boys and girls are negatively impacted by traditional teaching methods. Despite this fact, there are still teachers who remain hesitant to learn and implement different ways of teaching because of the time that was spent on a perfected system of teaching that worked over the years for them (McCusker, 2013). It is strongly suggested that the teaching methods that teachers use affect students' achievement and relationship with others in the classroom (Daniels & Bizar, 1998). Good teaching methods help to establish better rapport between teachers and students (Nguyen, 2011). High school geometry in particular is a course where teaching methods matter (Clements, 2003). My experience as a math teacher has made me realize that algebra focuses on my students' ability to think convergently in patterns and to manipulate abstractions. However, my students will also need to build on their ability to think divergently and to visualize abstractions through a geometry approach. According to Jones and Fujita (2001), a new pedagogy to teach geometry needs to be developed. Employing an effective teaching method to teach geometry is crucial to a successful learning experience for my students. One teaching method to employ is through a project-based learning (PBL) approach. PBL is a pedagogy, that helps to support the change and innovation that is needed to teach mathematics content in geometry.

Project-based learning (PBL) evolved as a result of problem-based learning. Beginning in the early 1980s, problem-based learning was used to teach clinical reasoning at medical schools. The purpose was to help students gain knowledge in the discipline by a hands-on approach and the ability to use problem-solving, reasoning and communication skills to solve complex and authentic everyday problems. By the 1990's, PBL was transformed by the Buck Institute for Education (BIE) with the decision to develop new teaching methods to meet the needs of regular students in their classrooms. PBL supports students' learning process to attain essential knowledge and life skills through an inquiry process that is built around complex, authentic and carefully designed products, and tasks. (Mergendoller, Markham, Ravitz, & Lamar, 2006). Schools utilizing PBL have seen increases in academic student performance and student satisfaction.

PBL is being widely adopted across the globe and is demonstrating performance increases in academics and in testing scores (Liegel, 2004). According to the George Lucas Educational Foundation (2004), students' who were in a program which emphasized project-based learning and technology improved by 26% in all subject areas. A study conducted on students at the Rocky Mountain School of Expeditionary Learning (RMSEL) revealed an 11.9 percentage point higher than schools which did not incorporate project-based learning in their instruction (Sterbinsky, 2002). Furthermore, the use of project-based learning with the support of multimedia technology, have increased students' score by 27 percentage points than students in urban and special needs school districts in reading, writing and math achievement tests (Liegel 2004).

Studies across the U.S. and international countries are revealing the beneficial influence of PBL on student learning. A 5-year study by the SRI international in California's Silicon Valley on the Challenge 2000 Multimedia Project showed student gains and increase in performance level in content mastery, and completion of assignment tasks as compared to non-participating students in the project (Penuel, Korbak, Yarnall, & Pacpaco, 2001). A three-year 1997 study of two British secondary schools—one that used open-ended projects (considered a similar approach to PBL) and one that used a more traditional, direct instruction approach—showed a significant difference in understanding and improved standardized achievement result in mathematics (Boaler, 1997). Schools are continually looking for solutions and inventive ways to improve the learning experiences for their students. However, some teachers and administrators remain reluctant to throw away their out-dated teaching methodology in order to start all over (Hosler, 2013). Nevertheless, even if the issue of putting more work on teachers is not considered, raising students' standardized test scores, improving student learning, and content understanding create a strong case to explore PBL.

A noted particular case is that of Manor New Tech High School (MNTHS) in Manor, Texas, which recognized the need for an environment that fosters student learning in the classroom, and adopted the PBL approach and continues to promote their successes to other high schools (Edutopia Staff, 2012a). Through the implementation of PBL, students at MNTHS developed better critical thinking skills, improved long term retention of content learned and increased students' and teachers' satisfaction with their learning experiences. As a result of PBL, students' success had increased at MNTHS and a large portion of students' high stake test scores rose from underachieving to high achieving, and continues to improve every year. At MNTHS, seventy-nine percent of Manor New Tech graduates had enrolled in two or four year colleges immediately after high school, surpassing the national rate of 79%. The school had outperformed the state of Texas and Manor Independent School District in the percentage of students passing state standardized tests in science, social studies, English, language arts and math (BIE, 2012). Additionally, ninety-eight percent of their senior population graduated, and all were accepted into colleges.

Many schools still remain committed to following very traditional methods in teaching, where the teacher lectures and students take notes. However, there are also many schools and districts that are implementing project-based learning as a component of a larger overhaul of their schools (Liegel, 2004). Schools such as Mountlake Terrance High School in Washington and Napa Valley High Tech School in California are the most recent schools that have implemented the PBL approach at their schools. King Middle School and Casco Bay High School in Maine have also adopted the PBL approach.

At Marriot high school, where I work at, we have students who have problems in retaining mathematical knowledge. Furthermore, most students lack the ability to comprehend mathematical content and motivation to become involved in their own learning. With PBL, my students may be able to connect to real-world situations with content and also to build meaning into their learning. PBL incorporates 21st century essential student “learning skills of communication and presentation skills, organization and time management skills, research and inquiry skills, self-assessment and reflection skills, and group participation and leadership skills” (BIE, 2012). The development of these skills benefit my students as they support them with their growth to acquire higher thinking skills. In PBL, hands-on and group discussion exercises are heavily used to allow for new ideas to develop and to foster critical thinking. PBL also allows the teacher to act as a facilitator, providing guidance as needed, while students become the center of the learning process as active learners. Furthermore, PBL helps students with their decision in making choices that are based upon their own ideas, opinions and voice, affecting project results and the learning process (Liegel, 2004). The flexibility to adjust PBL to meet my students’ need is a major advantage of the program. Most of my students would benefit from this opportunity to adapt instruction to meet their needs more readily. Overall, as stated by Baron and Hammond (2008), the implementation of PBL by teachers has helped students to engage more deeply into the learning process that challenges students to develop a positive attitude toward learning.

Purpose of the Study

The purpose of the study is to determine if project-based learning activities increased my students’ performance and engagement in geometry. Furthermore, the study is to explore my experiences in teaching my classes through a PBL approach. As project-based learning is a new concept to many public school teachers, many teachers and schools have differing ideas and perceptions of PBL (Ko, 2004). PBL is not a claim that can solve all students’ comprehension and learning problems in geometry, but it provides schools with an alternative teaching model that could be explored further or modified to best fit the needs for more effective teaching and learning for its students (Barron & Hammond, 2008). This study will also investigate the various learning conditions and situations in which my students are placed under during the process of PBL. Further, the study will also explore the effects of cooperative learning as compared to the effects of independent learning on my students.

Importance of the Study

At the school that I work at as a mathematics teacher, an urban high school in Hawaiʻi, referred to as Mariott high school, Adequate Yearly Progress (AYP) has not been met for the past 12 years. AYP is achieved when schools meet standards of student proficiency in reading and math based upon Hawaiʻi's state assessment (HSA) test results and have a 80% graduation rate. Current patterns and trends at Mariott school show large student retention rates and class failures in the area of mathematics. Geometry is a particular area that impacts my students' graduation success. My students tend to struggle with geometry problems in particular, hence lower math scores impact AYP and graduation rates. Annual school reports show that Mariott high school is struggling to meet its graduation rate and mathematics proficiency benchmarks set by the Department of Education in the state of Hawaiʻi. Beginning with the entering freshmen class of 2016, a full credit of geometry will be a requirement for graduation. For the past three years from 2009 to 2012, eighty-four percent of the students at my school have fallen short of earning a geometry class credit. According to the mathematics teachers at Mariott high school, many students become uninterested, uninvolved and unable to comprehend the concepts taught in class through a lecture and note-taking approach. My students' struggles may be related to their ability to connect mathematical concepts learned in class to their own constructed understanding of how these mathematical concepts apply to them or in their daily lives.

Creating a successful learning experience for my students is an important step to foster student learning. PBL is proven to have improved students' learning and achievement across schools that have adopted the program (Edutopia Staff, 2012b). PBL makes learning more meaningful to students, allowing teachers to connect real-world situations with classroom content through real-world problems and issues. The importance of PBL is its incorporation of 21st century learning skills in communication, written work, cooperative learning, critical thinking and the use of technology. PBL promoted the idea of cooperative learning, which serves as an important factor to improve students' learning. Through discussions and feedback from peers, new ideas can be created and developed thereby improving the learning process of students. PBL has been adopted in many schools and more schools are pondering upon the idea of adopting the program.

Since the National Defense Education Act Law 85-864 that was established in 1958, where the federal government invested large amounts of money to improve mathematics and science education, improvements in mathematics teaching has been a continuous discussion topic in many educational environments (Flattau & Bracken, 2007). Teaching mathematics has changed in many ways and has evolved from the traditional chalkboard to white boards and now to smart boards. Technology has played an important part in changing teaching methods. Calculators and sophisticated software to calculate and display problems visually has transformed the way in which students learn and understand math (Goldenberg, 2000).

The adoption of PBL provides schools with numerous benefits over the traditional teaching approach. It provides students with the opportunity to engage in hands-on learning, the discovery of concepts and knowledge, and allowing students to comprehend and create meaning to their own understanding (Noboro, 2012). By allowing my students to connect real-world situations to their own understanding of content, they can build an understanding on how classroom concepts can be used in the real-world. According to Pieratt (2011), PBL builds better working relationships between students and the teacher, thus lessening the embarrassment of asking for help from their peers or the teacher. Because PBL is student centered, teachers serve as facilitators and are able to interact with more students in the class (Froyd & Simpson, 2008). PBL serves as a concrete model to many schools that are deciding to change their teaching approach in their classrooms to improve student learning. Traditional methods of examination, homework, class-work assessment may not provide a conclusive view of students' work or progress. Schools that adopted PBL incorporated multiple ways to assess and provide teachers with an overall evaluation of the student.

Statement of the Problem

Although graduation rates have slightly increased over the past years, the dropout rate for high school students continues to claim more than one million students each year nationwide, nearly one in four students, and four in ten minorities do not graduate with their class (Civic Enterprises, 2012). Furthermore, many of these students are unprepared for college and lack necessary career skills. Many of these issues can be linked back to the teaching of mathematics that contributes to the issues of low student retention and comprehension. The problem is not from the difficulty of understanding content, but the instructional method used in the teaching of content in the students'classroom (Rotherham & Willingham, 2009). Since my students continue to struggle with understanding geometry concepts, learning these concepts should be reinforced with real-life application skills. The implementation of 21st century education models in high schools helps to prepare students to gain the needed essential skills and to become college and career ready (Civic Enterprises, 2012).

Over the last century, many different mathematics programs have been developed to address students' mathematical problems that students are still currently facing in learning how to solve problems. Schools across the nation that are adopting a 21st century learning model of project-based learning (PBL) are noticing the positive effects of the program in their classrooms. Through PBL, different teaching methods are used and practiced. Methods such as hands-on approaches, group work, and student partners are some of the learning and sharing concepts of the approaches that have been used, and are currently in use by mathematics teachers. Hands-on teaching approaches allow students the use of manipulatives to understand abstract ideas that have produced promising results. Student partners have also shown that partnering is an effective method to support student learning (Liegel, 2008).

Some teachers however have argued that PBL group work takes up a lot of class time to plan and to execute the projects (Yeung, 2008). Additionally, some of the teachers at my school feel that learning to teach in a different way not only requires extensive teaching modifications, but the extra effort to learn new technology. Some teachers do not feel obligated to change their teaching style and do not feel comfortable using new technology to teach (Bloemarts, 2013). However, there are many other teachers who have tried new teaching methods that have helped with students' content understanding (Edutopia Staff, 2012a).

Guiding and Research Questions

The study will address the following guiding and research questions.

Guiding Question: "What aspects of project-based learning (PBL) effect students' performance in geometry?"

Research Question 1: How does the use of technology in PBL impact students' comprehension of geometry concepts?

Research Question 2: How does hands-on experience in PBL when practiced by students show an impact on students' comprehension of mathematical concepts?

Research Question 3: How does the experience of group collaborations and discussions in PBL when applied as a problem solving strategy impact students' comprehension of mathematical concepts?

Research Question 4: What do students perceive to be the most impacting factor of PBL in learning mathematical concepts?

Method of Inquiry

The research technique to be employed will be both quantitative with pre- and post-test scores to be compared using a t-test analysis between two classes and through a qualitative approach with data collected through student interviews, observations, and reflections. The data collection methods used for this study are face-to-face interviews, document review of reflections from student portfolios, observations of my students' interactions, analysis of exams of my students' performance on Geometry comprehension. The statistical method to be used will be a t-test analysis.

Thematic coding will be applied to transcripts of the interview questions to generally seek my students' feelings towards doing math projects, difficulties encountered during the process of the project, whether technology helped in the process of the project completion, aspects learned by my students that would be helpful for them, and for future project completion, types of basic skills needed individually and as a group to complete the project successfully, and improvements that can be made. Observations will be analyzed for my students' behaviors when in groups such as figuring out new things, working cooperatively through discussions, sharing of tasks and information, and analyzing new data with minimal help from me.

Assumptions

With new policies and procedures being placed upon schools on a continual basis, schools have to constantly change and update all their new requirements. To be well informed and made aware of all new changes and updates require the dependency of people and an extensive amount of time of study and research. Presented below are the assumptions for this study.

Assumption 1. All participants are high school students in my classroom.

Assumption 2. Project-based learning is an alternative innovative teaching method.

Assumption 3. My school will experience greater instructional flexibility.

Assumption 4. Project-based learning will be used in my classroom.

Assumption 5. All my students will answer interview questions honestly.

Limitations

The participants in the study are my students at a public high school in Hawaiʻi and may exhibit a bias based on gender, culture, and race regarding project-based learning. Being their teacher, along with their peers, my students may feel pressured to participate in the study. Additionally, the mathematical understanding level of my students may create bias in their preference of project-based learning. Time that is allocated to conduct a thorough study may also be a limiting factor.

Delimitations

The study is narrowed to include only one public high school in Hawaiʻi. The small sample size and funding available are also delimiting factors.

Paper Organization

The paper will be divided into five sections which include the Introduction, Literature Review, Methodology, Analysis, and Conclusion. Section 1 of the study includes an introduction to the background of the study which introduces the problem statement, and the issues surrounding the study. This section will also include the purpose of study and research questions that will help to generate hypothesis for the study. The importance of the study will be noted along with alternatives. To be included in the section will also be the method of inquiry explaining the research technique, population group, and the data gathering instrument. The section will end with an explanation of the assumptions, limitations and delimitations. Section 2 of the study provides an inclusive discussion of the relevant literature related to the study. The detailed literature review in this section provides evidence, insights, and background information in an attempt to address the problems and sub-problems of the study. Section 3 of the study expands and provides a clear description of the research methodology used in the study. This section provides additional background and a discussion of the method of inquiry, research population and sample, and instruments used to gather the data. Section 4 includes the results of the findings of the study. The methods used to evaluate my students' performance in the study were the quantitative and qualitative studies. The quantitative studies include the tables, of the data summarizing the outcomes of the data analysis. The qualitative studies include descriptive comments in a narrative form. The comments of my students' work include common themes, patterns, and quotations from the subjects and also a description of events. The data is organized in a manner that addresses each of the research questions of the study. Section 4, begins with an introductory paragraph providing an overview of the organization of the chapter, and also includes a summary of the results of the study. This chapter is focused on the findings of the study with interpretation and discussion of the study. Section 5 focuses on the interpretation and the discussions of the study. In section 5, the quantitative study includes the results of the research questions. This section summarizes the entire study of PBL, and provides a comprehensive overview of the research findings. The discussion section organizes and answers the research questions. The data gathered from the study is analyzed and interpreted for the purpose of understanding how much have my students learned from working on the PBL geometry projects. Additionally, the experiences of my student's experiences will provide me with a deeper understanding of how my own teaching practice have changed and evolved. This chapter is unique, from my perspective because through the findings of this study, my students had the opportunity to express his or her impression of the study.

LITERATURE REVIEW

Purpose of Section

The purpose of the study is to see whether project-based learning (PBL) activities increased students' performance and engagement in geometry. Through an action research study, I hope to achieve a better understanding of how project-based learning within my classroom affected student achievement. The study does not address whether project-based learning is the only means of classroom instruction in geometry that will improve student achievement, nor does it confirm that project-based learning is the only explanation for gains in student knowledge of content. Because the focus will be on learning conditions and situations in PBL such as technology and group collaborations, the literature review begins with reviews of PBL in school situations. It continues with a discussion of what project-based learning is, a history of mathematics teaching, descriptions and research of mathematical concepts and their application, and the relationships between project-based learning and geometry, and project-based learning and technology. Then the literature review proceeds with a discussion of learning and motivation, project-based learning and motivation, and the implementation and assessment of project-based learning.

Project-Based Learning in Schools

A focus of many teachers is to provide students with learning experiences that enhance their knowledge. A variety of teaching methods and strategies have been tried by teachers throughout their teaching careers. Some of these methods and strategies have resulted in success, yet many have been discarded. The traditional approach of passive learning where students sit at their desks to take notes and work on assignments while the teacher dictates their learning, can still be seen in many classrooms. Methods such as working problems on the board or reviewing problems from textbooks are still evident in classrooms. An important part of a student's academic success can be attributed to the concrete understanding of abstract concepts. Tangible materials enable students to construct their own understanding about real objects to their own understanding of mathematical concepts (Cohen, 1990). Project-based learning is a teaching method that supports students' concrete understanding of abstract mathematical concepts. A discussion and sharing of conceptual ideas by students can help to further reinforce students' conceptual understandings. This process allows both the students and the teacher to work collaboratively on a learning project with the possibility of achieving a sense of wonder, self-discovery, success, motivation, and accomplishment throughout the learning process. When students had an opportunity to learn a subject using the PBL model, they became motivated and directly involved in the learning process, and as a result of this learning model, they showed academic gains (Intel Corporation, 2007). The Intel program is focused on the integration of information, and communications technology (ICT) into classroom activities, helping teachers to be more effective educators by training them on how to integrate modern tools into their lessons and promoting problem solving, critical thinking, and collaboration skills among the students.

Today, many educational systems are interested in creating an effective and stimulating environment that fosters students' success in the learning process. According to Barron and Darling –Hammond (2008), teaching methods that are effectively implemented, enable students to understand the content and become more engaged in the learning process. PBL students learn new concepts, are encouraged to investigate the subject, ask questions, and develop new knowledge through the learning process. PBL is designed around student centeredness that allows each student to draw on his or her previous knowledge, and to develop new knowledge. PBL offers a vision and a belief of how instruction should be delivered in the classroom. Many schools are now embracing the idea of incorporating PBL into their instruction as an effective alternative teaching method to use in the classroom. PBL requires critical thinking, problem solving, collaboration, and various forms of communication. Through this learning process students use higher thinking skills and learn to work as a team. For example, when PBL was used at Tri-Valley Middle School, the students worked on a project to research animal symbolism on the web. They designed three dimensional masks using innovative computer graphic programs, and then created and designed a digital movie of the mask making process. The students at Tri Valley Middle School, successfully incorporated PBL methods and state-of-the-art technology for the design of the three dimensional masks. As a result of using PBL, the students experienced a greater sense of satisfaction in the learning process, and gained a more holistic way of learning and looking at their project of designing masks (Boss & Krauss, 2008). Through the mask making process, the students also learned important skills of collaboration and teamwork. PBL proved to be very successful at Tri Middle School, because the students enjoyed the learning process, and learned the contents of the project through a variety of creative ways, such as a hands-on approach to learning, group discussions, and collaboration of ideas and concepts.

Many schools are using PBL in their curriculum. For example, at Vera O' Leary Junior High School, the students learned and practiced mathematical equations and problem-solving by relating the concept of how equations related to the reason rollercoasters moved in a particular path and direction. Through PBL, the students were able to view and understand this abstract idea, through exploration, group discussions collaboration of ideas, and hands-on learning (American Association for the Advancement for Science, 2009). PBL provided the students at Vera O-Leary Junior High School with a deeper understanding of roller coaster movement and increased their knowledge of the subject, through team work, group discussion and personalized learning.

King Middle School (KMS) and Casco Bay High School (CBHS) in Portland and Maine are two other examples of schools that have incorporated PBL into their curriculum. The implementation of technology in PBL meets the-state requirement to use technology to support a more effective and beneficial learning environment in the classroom. In the state of Maine the model of PBL meets the state’s standards of teaching 21st century technology skills in the classroom, and every student and teacher received a laptop to incorporate effective learning (Lester, 2011). Throughout the research there is an emphasis on the importance of 21st century technology skills for every student (Krulock & Landini, 2011). At KMS and CBHS the students worked in a project-based learning environment, and were presented with real- world projects to work on (Vega, 2012c). The students at these schools, used laptop computers to conduct their research, on the internet, and then they presented their findings through a video presentation (Barron, 2010). Through the process of using PBL, these students became outstanding investigators of knowledge, and the learning process transformed into a collaborative and inquiry process (Vega, 2012a). As an end result of incorporating PBL technology in the classroom, the students made remarkable improvements in their learning, and improved their academic skills and test scores. The students at KMS and CBHS outscored the state average, in six out of seven subjects, and moved into the status of the top third in performance in some subjects (Curtis, 2013).

Project-based learning (PBL)

Project-based learning is an instructional method that focuses on 21st century student learning methodology and includes challenging questions, or problems involving the students' problem-solving decision-making, and investigative skills. In addition, there is a critical reflection component that involves the teacher as a facilitator, and not as a lecturer (Froyd & Simpson, 2008). PBL integrates knowing and doing, and supports the notion that students construct learning for themselves through a driving question that encourages them to discover central concepts and principles of a subject through hands-on learning (Markham, 2011). The goal of PBL is to allow students to develop their own ideas and understanding. Furthermore, PBL is grounded in students connecting their classroom experiences to the real world. If successfully implemented, the use of PBL can help students develop new learning habits and critical-thinking skills. Project-based learning also allows students to connect their classroom experiences with the world outside the classroom. Through PBL, students develop new learning habits and critical-thinking skills that can lead students to other. Projects are also based on challenging questions or problems that involves students in designing, problem solving, decision making and investigative activities that ends with a presentation or a realistic product (Thomas, Mergendoller, & Michaelson, 1999). Different from a traditional way of learning, such as note-taking, listening to a lecture solely, and following the directions of a teacher in a classroom setting, PBL allows students to manage and organize their own time and work, and make the decision to spend as much time on a certain area of learning as needed. Collaboration and individual work is emphasized in a PBL classroom, where discussions among the group help to generate new knowledge. Students working independently, learn to take responsibility to make choices, which may help to increase students' involvement. Collaboration among groups, build teamwork with the opportunity to listen to other members' ideas and suggestions are commonly practiced in PBL. The main focus of PBL is the connection of real-world problems to classroom content and to capture students' attention that encourages them to apply new knowledge in a problem-solving context. In a PBL classroom, the teacher's role is that of a facilitator, who develops meaningful tasks, provides guidance and support to develop social skills, and assesses knowledge that is gained from experiences. PBL is a method of learning where students' explore the learning process, discover new ideas through a creative process, and develop higher level thinking through self-discovery.

History of Mathematics Teaching

The first historical record of mathematics teaching was documented by the mathematical methodology textbooks written in approximately1800 BCE. Some of these textbooks were discovered in ancient Mesopotamia, where the skills of multiplication, division, and solving equations were first practiced and demonstrated other kinds of mathematical textbooks were also developed by the ancient Egyptians, such as the Rhind Mathematical Papyrus and Moscow Mathematical Papyrus. The information provided in these textbooks were the instructional guides for educating the people in ancient civilizations.

The teaching of elementary mathematics had been the educational focus in ancient Egypt, Greece, and the Roman Empire. Not everyone received an education. Only the male children of the wealthy class were allowed the opportunity of an education. However, beginning in the fourteenth century, the structure of classical education was developed in Europe that focused on arithmetic and geometry. Geometry was taught universally through Euclid's book "Elements". Apprentices with masons, merchants, and money lenders learned practical arithmetic that related to their work. The Renaissance period focused on the study of natural, metaphysical and moral philosophy and these subjects were given a higher priority than the study of mathematics because of its relation to commerce and trade. Commercial pursuits were considered of the lower classes and the aim of learning math was to build profit requiring only enough knowledge of math to determine costs and revenues. The mathematical textbooks focused mainly on daily practical problems. Many of these problems were geometry, elementary number theory and astrology. The problems also focused on problems with solutions, therefore some student to teacher interaction was required. However, the sixteenth century was a period that focused mainly on using geometry concepts to design structures and weaponry such as boat hulls and cannons, thus making algebra concepts as a secondary priority.

Different from the sixteenth century, the seventeenth century was a period in which the goal was to implement more modern approaches to teaching mathematics. This century was an intense activity and innovation period in mathematics (Mathematics, 2014). During this period, mathematics was focused on formal mathematical analysis as a priority over geometry concepts. The Industrial Revolution, which began in the eighteenth century and escalated in the nineteenth century, brought on new concerns. Urban populations increased and the challenge to Euclid's truth became important with the discovery of Neptune. The uses of calculus in engineering, physics, and astronomy also became the focus of study during this period (Mathematics, 2014). Basic understanding of numeracy to tell time and to perform simple arithmetic became a necessity. These skills were also brought into the public education system.

By the twentieth century, mathematics education became a part of a school's core curriculum. The standards-based education reform movement became a focus where the emphasis was on conceptual mathematical understanding, and student-centered learning. This idea brought on various changing ideas concerning the goals and methods of mathematical education. As a result, reform-based standards and curricula were adopted. The adoption of reformed standards was met with opposition from math traditionalists, demanding a return to a traditional direct instruction method. Because of opposition, some schools supplemented standards-based curricula with forms of traditional, direct instruction. The standards-based education reform movement was based on research that emphasized problem solving, mathematical reasoning, conceptual understanding, and student-centered learning. The standards emphasized the goals of equity in teaching mathematics, conceptual understanding of mathematics and less on memorization. The Core-Plus mathematics curriculum was developed as a result of the standards and emphasized real –world applications and teaching and learning mathematics through problem-solving. However the Core-Plus mathematics project was met with opposition. Complaints were made by students that the math courses they took at their schools placed them in remedial math classes in college. In 2009, the National Governors Association (NGA) and Council of Chief State School Officers (CCSSO), teachers, content experts came to work on developing standards to address these issues (Corestandards, 2012). This led to the widespread adoption of the common core state standards that emphasize that students' should be college and career ready, and also acquire 21st century skills in teamwork, problem solving, and technology skills (Junior Achievement, 2010).

Mathematical Concepts and Application

Mathematics is defined as the science of numbers and their operation, interrelation, combination, generalization, and abstraction of space configuration, and their structure, measurement, transformation, and generalization (Merriam-Webster, 2013). Mathematics is perceived as a subject area that uses direct instructions in very traditional ways. Studies have shown that students educated in a traditional learning environment showed a lower level of achievement on standardized tests, projects tests, and on project tests dealing with realistic situations, than students who learned through project-based learning (Boater, 1998). Many students today are struggling in the traditional school setting to understand mathematical concepts. According to Polya (2000), there are four important steps to assist a student in understanding and solving a math problem. These four steps are: understanding the math problem, devising a plan to solve the problem, carrying out the plan to solve the problem, and checking the results after solving the problem. These basic solving techniques also emphasize a connection between the student's prior mathematic knowledge and concrete understanding of mathematics, which has proven helpful in solving mathematic problems. In contrast to learning mathematics in the traditional way, project-based learning is an effective alternative because it gives the students more opportunities to think critically, present their own creative ideas, and communicate clearly about mathematics with their peers. (Krulik & Rudnick, 1999, Lewellen & Mikusa, 1999, Erickson, 1999; Carpenter et al.,1993; Hiebert et al., 1996; Hiebert et al., 1997).

Students in traditional mathematics education environments learn through exercises, rules, and equations. In this form of learning, the students are drilled on reciting formulas, mathematical rules, and facts (Understanding Mathematics, 2006). In contrast, the sharing of mathematical ideas is essential in PBL, because it provides students with the opportunity to critique and refine others' ideas and understandings of mathematics (Access Group, 2013). Students in PBL environments have a greater opportunity to learn mathematical processes associated with communication, representation, modeling and reasoning (Smith, 1998; Erickson 1999; Lubienski, 1999), compared to the traditional method of learning. When students use PBL, they interact and work more cooperatively, develop better mathematical skills and develop a deeper understanding of mathematical concepts (Artzt & Armour-Thomas, 2008). Students learning geometry concepts in PBL environments are involved in the learning process through hands-on learning, exploration, team-work, collaboration of ideas, and 21st century use of technology.

Project-Based Learning and Geometry

An important factor in teaching geometry in the school system is to help students integrate and apply mathematics concepts. Beginning with the class of 2016, geometry will be a graduation requirement in Hawaiʻi public schools. Studies have shown that the American mathematic curriculum in elementary and secondary schools is a serious dilemma for students learning geometry concepts (Jones & Fujita, 2001). Several surveys conducted in the U.S. schools have indicated that about 30% of students who completed a full-year of geometry. Of these, only about 75% have mastered the geometry curriculum. (Jones & Fujita, 2001). Many geometry classes in the public schools are taught through traditional methods of lectures and note-taking. Students exposed to this method of teaching in geometry have shown low levels of academic performance. However, when students experience the instruction of geometry through more creative methods, their curiosity and is encouraged and their attitude toward learning mathematics (Jones & Fujita, 2001). PBL can enhance the effectiveness of teaching and learning geometry. PBL methods encompass the essential skills that are needed to support-student learning experiences, and provide the central framework upon which the teaching and learning of geometry concepts are built (Thomas, 2000).

It is important that geometry is presented to students in the early years of secondary education in an interesting, clear and meaningful fashion, to provide students with the opportunities to investigate spatial ideas and real-life problems (Jones & Fujita, 2001). The goal of learning geometry is to learn: spatial awareness, geometric intuition, deductive reasoning, and the application of geometry through modeling and problem-solving skills for the real world. Through PBL students are encouraged in the classroom to construct their own work by the geometric concepts learned in the mathematic curriculum. The main concept of teaching geometry through the PBL model is to incorporate learning with real-life problems, achieve a connection between the cognition and professional knowledge of the learner and the problems, learn in small groups, and allow the teacher to assist the students as a facilitator, rather than as a leader. PBL methods in the academic domain can improve geometry teaching and help students apply the learned knowledge (Chen, 2013).

Learning and Technology

Technology in the 21^{st} century has transformed the way professionals perform their jobs. For example police officers search online data bases to access a driver's driving records. Mechanics use computers to diagnose which part of an automobile's engine needs to be serviced. Family doctors use technology to scan their patient's medical conditions. Technology is a great asset, because it enables people to perform their jobs more efficiently and effectively (Ertman, 2010).

Technology changes the way teachers teach, and in today's world teachers are integrating technology into their curriculum and learning environment (Edutopia, 2013). Teachers have also increased their personal and professional use of computers. Based on the Speak Up 2007 national survey, the major uses of technology facilitates learning comprised of: asking students to complete their homework assignments using computers, and assigning practice work on the computer. When teachers use technology, they increase their effectiveness as a teacher, and their students benefited in the learning process (Edutopia, 2013).

Teachers are finding value in using technology in the classroom, to facilitate positive learning outcomes among their students. The use of technology in the classroom empowers students to demonstrate their creativeness to the teacher, as well as with other students. When classroom technology is used effectively, students can acquire useful survival skills to use in a highly technological and competitive economy (Edutopia, 2012). Technology supports active engagement in learning, participation in group learning, and interaction and feedback through the internet and social media. The use of technology has become a big part of a students' educational experience (Crook, 2012). Technology also supports all types of learning, through multi-sensory learning technology. Technology has become an important tool in education today because it supports the teacher in curriculum planning and the students in the learning environment by helping them to develop the ability to research, acquire, and analyze new information on the internet for individual and group learning projects.

Learning and Motivation

Research indicates that motivation plays an important role in influencing students' learning and achievement in the classroom (Ames, 1990). When students are challenged and motivated, they take more pride in their achievement and persistence in their education. When instructional materials are challenging, students have more choices and may experience greater opportunities for self-determination, positive motivation and high achievement in the learning process (Hidi & Harachiewicz, 2000).

Effective schools and effective teachers are those that develop educational goals, beliefs, and attitudes in students that contribute to quality education and involvement in learning (Ames, 1990). When teachers are effective, they promote a learning environment where the students develop a sense of inner motivation, thus striving to learn and achieve their educational goals. Technology in the 21st century also motivates students in the learning process. It maintains the students' interest, builds the students' self-confidence and knowledge in the learning process (Heafner, 2004).

A study on the connection between learning and motivation found that self-determination is key to why learning occurs within particular settings (Deci & Ryan, 2004). The focus of this theory is why people learn within a particular setting, and why they engage in learning. Students are motivated to learn for internal reasons such as their interest and personal fulfillment and for external reasons such as rewards. Intrinsically motivated learning originates out of an interest and enjoyment for learning. When students are internally motivated, they have an interest and enjoyment towards learning and are more likely to succeed in the classroom (Kyndt el al, 2011). Students who are motivated have a sincere interest in the topic regardless of the positive rewards. Intrinsic motivation is important because it is influenced by one's own challenge, curiosity, control, fantasy, and relatedness. Students who are motivated, also thrive in the educational setting, and achieve a higher quality of learning.

Cooperative learning is defined as small organized group of students, which help each other to learn academic content (Mayer & Alexander, 2011). This form of learning is effective in the classroom because it helps build teamwork among the students, and encourages peer support and a united connection in the learning process. Cooperative learning and project based learning help students engage in the learning process, take an interest in learning, and become a motivated learner. When students work cooperatively in the learning process, the results are a positive learning environment, motivated students who gained knowledge through the learning process (Roger & Johnson, 2009).

Project-Based Learning and Motivation

According to teachers, students learn best when they are interested and motivated about a topic that brings meaning to them. Keeping children engaged and motivated in the classroom is challenging, even for the most experienced teachers (Yates, 2012). According to Iadiapolo

(2011), students became engaged and exercised more higher-order level thinking skills when they were involved in a realistic setting for the application and skills they were learning (Iadiapolo, 2011). Most of the time students asked teachers questions about the relevance of what they are learning, or they become bored because they felt no connection to what is being taught. Furthermore, students' motivation decreased when they were required to memorize facts or formulas (Railsback, 2002). PBL built and related students' own experiences, learning styles, and ability levels to what was presented in class. This approach may help to keep students interested in what they are learning and further connect their learning experiences to real-life situations. Projects served to build bridges between the phenomenon in the classroom and real-life experiences; the questions and answers that arise in their daily lives are given value and are shown to be open to systematic inquiry (Blumenfield, 1991). PBL projects incorporated content standards and are organized around a driving question. The students' task is to work towards this goal of answering the driving question with an end product or solution to the problem in mind.

To keep the interest of students in focus, PBL employs technology which most students are fascinated to use (Boss & Krauss, 2008). The use of computers to surf the internet for web based information for projects is a factor in bringing change in the learning processes in schools (ChanLin, 2008). Through the use of PBL, students engaged in cooperative learning and discussions among groups to arrive at conclusions and solutions. Interacting actively with group members, help and assistance, sharing of resources, and encouragement for each member in the group could be gained. Cooperative learning also helped to enhance intrinsic motivation because of its high level of independence in deciding how a project should look like and the chance to work closely with their classmates (Liu et al., 2004). Students are most often motivated to work toward a set goal that brings meaning to them. A final project such as a pedagogical instrument increases pupils' motivation and interest (Wright, 2012). According to Wright (2012), a culminating project or a presentation created a purpose and stirred enthusiasm for students. Additionally, students who often struggle in most academic settings find meaning and justification for learning by working on projects (Nadelson, 2000).

Project-Based Learning and Technology

Project-based learning is an instructional method that focuses on creating meaning to students' understanding of concepts in a discipline. The process to create this meaning to the student involves problem solving, investigating, and constructing personal knowledge skills. Students can acquire these skills through the practice and use of technological tools. Information resources, such as the World Wide Web play an important part in a PBL learning environment (Land & Greene, 2000). The use of the computer to search for information allows students to find answers for a deeper understanding of a concept which may not be provided in class. When an effort is put forth to research a topic of interest, value is added to that information. When students are actively involved in the process of learning, a deeper understanding can be achieved. Technology in PBL shifts the focus away from the teacher and puts the responsibility on the student to create that deeper meaning. Students' construct meaning to classroom content by connecting the information they gained or gathered to their own experiences and prior understandings. Students use technology to internalize and personalize these ideas which may be applied to different contextual situations.

An important component of PBL is for students to develop critical thinking skills. As stated by Roschelle (2000), the use of computer technology not only supports learning, but is useful in the development of higher-order critical thinking skills, analysis, and scientific inquiry. For example, the multiple tasks, requirements and issues to manage a project require students to effectively plan, research, and find solutions. The use of technological tools and software such as spreadsheets, word processing, search engines and PowerPoint organizes and supports these multiple tasks requirements. It is also necessary for students to have the ability of speaking in front of their peers and to express their ideas. The use of technological tools and software such as PowerPoint and word processing allow students to organize their ideas and build presentations to practice their oral skills in front of their peers.

As reported by Moursund (1999), the use of technological information in a PBL curriculum benefit students in multiple ways such as student self-reliance, how to design, carryout, and evaluate a project in an authentic and challenging environment. These skills are essential elements for completing projects, but are also necessary skills needed in a real-world environment. Students are not only learning these needed skills, but reinforcing them through practice. Additionally, the utilization of technology in a PBL curriculum allows for students with various intelligences to demonstrate and use them in different ways. Technology accommodates for the various intelligences in musical, technological, artistic, and learning language as students collaborate and develop plans to meet project deadlines. Project-based learning instruction in the classroom provides the student with a practical real-world way to use technology and expand their knowledge in a creative and motivating way.

Implementing and Assessing of Project-Based Learning

Research on PBL has illustrated that this method of learning has helped students develop the knowledge and skills necessary to be successful in this rapidly changing world. Near the end of a completed project through PBL, the teacher implements an assessment plan to evaluate the learning process of the students' project. The assessment plan and implementing of PBL serves as an important tool, used to determine how much the students have learned, and how to help the students reach their educational goals.

Through collaboration and inquiry approaches to learning studies have shown that the three components of instruction which are assessment, classroom activities, and curriculum are interdependent (Barron & Hammond, 2008). Through 21st century projects, teachers are incorporating new approaches to making learning assessments more meaningful. The implementation of performance assessment enables the students to learn and apply the desired learning concepts and skills in a disciplined way. In addition, evaluation tools, such as assignment guidelines and rubrics define what constitutes good work and effective collaboration skills for students. Formative assessments serve as a guide to give feedback to students and to shape their instructional program throughout a project (Barron & Hammond, 2008).

The type of assessments teachers use for PBL plays a significant role in shaping the students' work they are undertaking. Research suggests PBL demands structured performance assessments, to define the learning tasks the students are engaged in, and to evaluate what the students have learned. Good performance assessments stretch students' thinking and planning abilities. There are many ways in which assessments contribute to a student learning, for example exhibitions, projects in multimedia presentations, web pages, artwork, and power point presentations. PBL assessments incorporate 21st century skills of collaboration, presentation skills, critical thinking skills, and covers mathematic standards with an in depth focus (Edutopia, 2011). PBL also provided the evaluation method of formative assessment, use of student's reflections, observation, and interviews used to provide guidance for students and teachers based on their work performance and work successes. Successful implementation of PBL is dependent on the successful planning and implementation of the project, developed by the teacher. PBL transforms learning into an active student-driven experience, using technology tools for inquiry, collaboration, and connection to the real-world beyond the classroom.

Conclusion

Project-based learning is a dynamic approach to teaching in which the students explore the real world's problems and challenges. With PBL this type of active and engaged learning, inspires students to obtain a deeper knowledge of the subjects they are studying. PBL is an emerging teaching methodology that is being implemented in many educational institutions in the United States.

Project-based learning is being used as a method for instruction and learning in the middle and high school mathematic classrooms. Through PBL students are more actively engaged in the learning process. Research shows that students engaged in PBL transfer their knowledge to situations outside the classroom. Projects allow students to transfer their mathematic skills to other disciplines and to real-world problems. For the mathematics teacher there is a wealth of published literature and publications that inform and instruct teachers on ways to teach and implement PBL into the classroom. Project-based learning projects and method can vary from classroom to classroom. There are many attributes to using PBL methods in the classroom, such as: it allows the students a degree of choices to study, it focuses on learning methodology through challenging questions linked to real-life problems, and the methodology involves problem solving, decision making, and reflective skills (Boss, 2011). PBL is also a learning style that integrates technology into the classroom instruction, supports learning through active engagement, and incorporates group interaction to solve and work on projects connected to real-world situations. Research indicates that the use of technology engages students to experience more effective learning in the classroom. More importantly the subject of geometry is an area of study that requires students to understand abstract ideas. PBL helps to engage the mathematic student's learning process through technology, graphics, pictures of abstract shapes, creativity, and higher order thinking. Through this type of learning students are inspired to obtain a deeper knowledge of the subject they are studying.

METHODOLOGY

Purpose

The purpose of the study was to see whether project-based learning activities increase students' performance and engagement in geometry. Through an action research study, I hoped to achieve a better understanding of how project-based learning within my classroom affected students' achievement. The study was not to prove whether project-based learning is the only means of classroom instruction. The study was also not to confirm that project-based learning is the only explanation of how students' gained content knowledge.

Purpose of Section

The purpose of this section is to describe the methodology of the research to be conducted that analyzes the main issue based on data collected. This section describes the method of inquiry, population, sampling technique, measurement and instrumentations used for the data, and summary of the section.

Section Organization

Section three discusses in detail the research design and methodology used in the research by summarizing the entire section. This includes the method of inquiry, population and sample, and a summary.

Method of Inquiry

The research technique employed was a mixed method of quantitative and qualitative research. The data collection methods that were used for this study were face-to-face interviews, document review of reflections from students' portfolios, observations of students' interactions, analysis of examination of student performance on geometry comprehension, and t-test analysis. The target population included two geometry classes taught by the same teacher consisting of about thirty students each. The classes were a mixed group of students, ranging from 9th grade to 12th grade. The exact gender breakdown was unknown; however a current geometry class consists of eighteen males and twelve females. Interviews were conducted once every two weeks with a different student during the duration of the project. I interviewed students about their understanding of math content, and if the students felt that project-based learning increased their performance and engagement in geometry. Learning strategies such as collaboration, hands-on practice, technology use, and communication skills were utilized. Journals of reflections and evaluations were collected from each student.

Table 1 illustrates the PBL treatment that I used with my students. Group 1 received PBL activities first and Group 2 received it second. Then the groups switched and experienced non-PBL instruction. My students in the PBL classes were asked to answer the two authentic questions:

1. How can Engineers use triangles to construct strong, stable and safe structures?
2. How do you use math statements to advertise a new product or invention?

Table 1

PBL treatment on two student groups

Authentic Question	PBL	Non PBL
1. How can Engineers use triangles to construct strong, stable and safe structures?	Group 1	Group 2
2. How do you use math statements to advertise a new product or invention?	Group 2	Group 1

Population and Sample

Population

The study took place in an urban high school in Hawai‘i. The school consisted of ninth, tenth, eleventh, and twelfth grades and has a population of 1782 students; 637 ninth grade students, 471 tenth grade students, 377 eleventh grade students, and 297 twelfth grade students. Of the 1782 students, 53% received free and reduced lunch. In terms of their ethnic background, 84% were Asians, 7% were white, 6% were Micronesians, 2% were Hispanic, 1% was Black, and less than 1% was American Indian.

Sample

All students were invited to participate in the project-based learning project, but participated if both the parent/guardian consents and student assents were signed and returned with approval. Students' background consisted of different ethnic groups that included Chinese, Japanese, Micronesians, Vietnamese, Laotians, Koreans, Filipinos, and Pacific islanders. Students had different levels of abilities and background in basic mathematics. Many of the students were immigrants who arrived from China, Hong Kong, Philippines, Korea, and the Micronesian islands.

Measurement and Instrumentation

The data collection instrumentations that were used to gather information were face-to-face interviews, document review of reflections from student portfolios, observations of students' interactions, analysis of exams of student performance on Geometry comprehension, and t-test analysis on student examinations.

Instruments and Data Collection Procedures

Face-to-Face interviews

Interviews were completed by me as the teacher-researcher and recorded on the interview instrument. Students were presented with verbal instructions prior to the interview process. Thematic coding was applied to transcripts of the interview questions to generally seek students' feelings towards doing math projects, difficulties encountered during the process of the project, whether technology helped in the process of project completion, aspects learned by students that were helpful for them, and for future project completion, types of basic skills needed, individually and as a group to complete the project successfully, and improvements that can be made. Students' interviews were collected to determine if students understood the learning objectives, and if project-based learning benefitted them in their learning. Interviews were conducted to gather more in-depth information regarding their feelings towards project-based learning. Interviews helped to determine students' understanding of math content and if the students felt that project-based learning increased performance and engagement in geometry.

Document review of reflections from student portfolios

Students' reflections were passed out for students to complete daily. Students wrote down their responses to the reflection questions on the reflection instrument. Completion of daily reflections was a part of the project. The questions that the reflections addressed were:

1. What did you learn today?
2. How did you feel about your work today?
3. What class activity was most useful to you?
4. What class activity was least useful to you?
5. What do you need to continue to work on?

Responses to the reflection questions were analyzed, to obtain a perspective of students' feelings and attitudes towards project-based learning. Students' written reflections were collected to help assess whether students understood the learning objectives, and if project-based learning was useful in their learning. Reflections were conducted to gather more in-depth information regarding their feelings toward project-based learning. Student reflections helped teachers to determine students' reaction to the effectiveness of project-based learning.

Observations of student interactions

Observations of students' interactions during the process of the study were completed by me as the classroom teacher and recorded on the observations checklist instrument. I circulated around the classroom to observe individual students in their groups. Observations were analyzed for students' group behaviors, such as figuring out new things, working cooperatively through discussions, sharing of tasks and information, and analyzing new data with minimal teacher help. Students' observations were collected to determine if students understood the learning objectives, and if project-based learning benefitted them in their learning of geometry. Observations were conducted to gather more in-depth information regarding their feelings towards project-based learning. Observations of what worked and what didn't in a particular class as a whole provided valuable information to mentally adjust the teacher's attitude. Additionally, observations allows teachers to make adjustments and immediate changes to the class or lesson.

t-test analysis on student examinations

Student quizzes were passed out to students to complete at the beginning of the class period. Students were presented with 5-6 quiz questions in which certain quiz questions were used for the research study. A final examination was given at the end of the project to answer certain questions that are used for the research study. Students wrote down their answers on the quiz and final examination instrument. Exams were given to continuously monitor and asses students' progress. Test scores were compared using t-test analysis between two geometry classes. Students' quizzes and final examination scores helped to determine if project-based learning was successful in learning of mathematics concepts, skills, and learning objectives. Data collected were analyzed for impact and effectiveness of project-based learning on students' learning of mathematical concepts. Additionally, data collected by this instrument provided information about students' understanding of geometry content.

Summary

The study was conducted over a brief period of time and was both qualitative and quantitative. The method of data collection were through face-to-face interviews, document review of reflections from students' portfolios, observations of student interactions, analysis of examinations of students' performance on geometry comprehension, and t-test analysis of students' examinations. The method of inquiry that was used to conduct the study was presented by describing the population being surveyed, the data gathering instruments used, and data collection procedures. The purpose of the study was to see whether project-based learning activities increased students' performance and engagement in geometry.

DATA AND FINDINGS

Introduction

This mixed methods study was designed to uncover and describe the dynamics of group participants working on project-based learning tasks through group collaborations, technology use, critical thinking, and hands-on experiences. The purpose of this study is to determine themes, experiences, and decisions made by the students as they worked on a variety of projects.

Three sources of data were collected and analyzed to triangulate those results: written individual student reflections, student interviews, and observations of student groups working on the projects. The research design also utilized the t-test for quantitative analysis. The following research questions guided this study:

R1: How does the use of technology in PBL impact students' comprehension of geometry concepts?

R2: How does hands-on experience in PBL, when practiced by students, show an impact on students' comprehension of mathematical concepts?

R3: How does the experience of group collaborations and discussions in PBL, when applied as a problem solving strategy, impact students' comprehension of mathematical concepts?

R4: What do students perceive to be the most impacting factor of PBL in learning mathematical concepts?

The remainder of this chapter will describe the population, data collection, analysis of data, research questions, findings, and a summary.

Population Description

The participants in this study were 60 of my high school students located in the state of Hawaiʻi. The students in the study were 85% Asians, 13% Polynesians, and 2 % Caucasians consisting of 28 females and 32 males. Their ages ranged from 14 to 17 years of age. All students in the study are from the lower middle socioeconomic status or above as indicated in school records. Most of my students took prerequisite math courses leading up to the PBL geometry course. Data collection of my students occurred in a computer-equipped classroom with about 35 computers.

Collection of Data and Data Analysis

Data was collected over a four-week period during a total of 10 class work sessions. My students were audio recorded as they were interviewed after school for 5 minutes each. Two classes of 30 students each met 10 times in a four-week period. They were chosen randomly to form 6 groups with about 5 members in both classes. At the end of each class session, students provided a written reflection. Group 1of the first class consisted of 2 females and 2 males. Group 2 in the first class consisted of 3 females and 3 males. Group 3 in the first class consisted of 3 females and 2 males. Group 4 in the first class consisted of 3 females and 1 male. Group 5 in the first class consisted of 3 males and 3 females and Group 6 in the first class consisted of 3 males and 2 females.

Group 1 in the second class consisted of 2 females and 3 males. Group 2 in the second class consisted of 3 females and 3 males. Group 3 in the second class consisted of 1 female and 4 males. Group 4 in the second class consisted of 4 females and 2 males. Group 5 in the second class consisted of 3 males and 1 female and Group 6 in the second class consisted of 2 males and 2 females.

Reflections

Microsoft Excel and Word software were used to analyze the information from the reflections of individual students in the study. My students completed daily reflections at the end of each class session. The reflection questions include:

1. What did you learn today?

2. How did you feel about your work today?

3. What class activity was most useful to you?

4. What class activity was least useful to you?

5. What do you need to continue to work?

Microsoft Excel and Word were used to produce word groups to identify the most dominant words in the reflections and the relevance of the words according to frequency of use. The word groups were the basis of the coding and categorization process, thus creating the developed themes for analysis.

Interviews

Microsoft Excel and Word were also used to transcribe audio files from my students' interviews, which were conducted after school. Word queries were used to identify the most often used words within the transcribed audio files. The interview questions include:

1. What went through your mind when you first learned about this project in class?

2. What were some of the things about the project that motivated you?

3. How did you go about completing the project task?

4. What types of technology tools did you use?

5. What were some of the most important things you learned while in the process of working on your project?

6. Would you have preferred to write a research paper or do this type of project?

7. What are the skills most needed in completing the project, and how do you improve these skills?

8. What are the strengths and weaknesses in your project?

9. What suggestions would you make to me about implementing or modifying the project?

Microsoft Excel and Word were also used to identify the most dominant words and their relevance according to frequency of use (see Figure 1 to Figure 12).

I	so	of	phone	what	all	on	presentat	understand	we	the	cooperating
managed	I	us	also	to	the	the	used	conditional	were	concepts	use
the	just	were	internet	do	work	essentials	the	statements	all	collaborate	computer
assignments	did	trying	all	and	I	like	internet	by	trying	and	and
of	it	to	were	to	organized	the	to	looking	we	discuss	calculators
the	to	finish	put	apply	the	conditional	get	at	all	to	putting
project	get	but	to	ourselves	work	statements	reference	Divided	use	get	all
for	it	some	use	we	by	and	used	up	laptops	the	the
my	over	were	for	collaborat	sorting	the	power	the	calculator	work	materials
group	with	lazy	info	and	out	invention	point	work	and	done	together
cause	I	and	on	discussed	which	then	and	some	internet	manage	taking
they	did	did	the	all	ones	we	videos	did	help	the	the
didn't	it	nothing	project	the	to	started	to	the	us	assignments	time
do	by	we	hands-on	people	do	to	advertise	building	apply	by	helped
anything	dividing	used	activity	were	I	create	hands-on	parts	it	listening	me
and	the	laptops	help	doing	first	our	activity	who	to	completing	in
were	work	calculator	us	nothing	did	video	helped	knew	project	project	using
lazy	most	and	understoo	did	research	and	us	how	and	by	triangles
CPCTC	assigning	work	for	each	other						

Figure 1. Frequency of word use in class 1 group 1.

We	type	we	because	and	computer	we	the	on	bridge	helps
just	and	had	the	IRL	for	needed	quarter	time	talk	group
follow	glue	our	glue	we	some	group	we	worked	about	learn
all	our	meeting	dries	our	invention	do	needed	together	what	and
group	activities	about	slowly	some	ideas	better	group	on	group	fun
steps	is	the	we	troubles	and	by	set	time	do	for
group	basically	project	used	getting	we	communicating	up	group	next	us
we	group	we	communication	ourselves	used	better	dates	finish	everyone	we
completed	study	cant	our	together	the	cooperating	sooner	everything	share	worked
our	guide	think	control	group	phone	because	and	computer	ideas	together
project	we	of	our	we	our	none	make	for	and	group
everyone	just	our	group	managed	record	of	sure	presentation	know	figure
group	all	invention	our	our	it	use	were	it	what	out
our	decide	because	managing	set	helped	really	all	helped	they	the
group	group	all	where	group	us	knew	available	us	should	hard
go	finish	the	were	times	cooperate	each	talked	learn	do	problems
there	everything	ideas	gonna	our	better	other	all	everything	practice	because
part	because	were	meet	do	our	and	the	we	and	of
of	we	taken	we	the	helped	it	time	were	thought	teamwork
our	want	the	communicate	work	us	was	goggle	learning	phone	and
assignment	it	glueing	through	we	understand	the	docs	by	computer	difficulty
we	our	was	our	used	our	beginning	Did	building	and	pushes
used	pass	hard	computer	the	better	of	everything	the	powerpoint	us
real	in	math	understand	help	one	through	how	group	another	texting
world	the	is								

Figure 2. Frequency of word use in class 1 group 2.

We	computer	think	the	mainly	group	work	we	are	we	docs
share	online	we	project	just	class	it	mostly	hard	didn't	and
out	search	think	we	the	time	was	discussed	our	have	everyone
the	It	what	also	computer	took	rather	on	contact	teamwork	knew
work	help	we	worked	made	our	hard	facebook	with	Split	who
and	me	need	together	it	finish	a	about	we	group	was
cooperate	makes	our	when	fun	our	laptop	how	couldn't	work	doing
with	group	invent	we	and	project	group	our	finish	so	what
one	easier	how	needed	easier	though	internet	do	group	everyone	use
another	our	our	our	our	we	a	certain	slide	is	internet
we	understand	invent	get	understand	could	video	group	presentation	doing	group
work	rather	it	the	pretty	film	cam	and	since	something	research
a	than	and	work	easy	group	It	planning	group	use	our
lot	just	how	done	no	advertisement	helps	out	members	computer	see
and	learning	our	the	argument	we	us	project	were	group	which
hard	group	present	group	all	made	our	there	a	information	bridge
our	other	We	and	of	sure	understand	were	little	showed	stable
complete	people	all	I	us	everyone	people	group	clueless	me	working
the	we	communicated	worked	working	had	better	problems	We	triangles	together
work	work	and	well,	equally	group	and	with	did	are	monitored
group	together	talked	we	we	necessary	cooperate	time	not	more	through
the	and	our	didn't	tried	group	with	and	manage	stable	goggle
project	share	each	have	our	our	each	cooperation	our	people	wisely
we	what	other	any	balance	complete	other	some	time	group	better
use	they	about	problems	out						

Figure 3. Frequency of word use in class 1 group 3.

We	we	We	group	have	We	we	organized	the	to	we
share	use	talk	shared	to	try	make	I	assignments	build	were
out	computer	about	information	prove	to	Some	understood	together	bridge	going
the	online	whats	to	what	work	stuff	what	and	find	to
work	search	the	complete	statement	together	happen	I	organized	blueprints	do
and	It	order	the	is	to	so	was	which	help	smoother
cooperate	help	of	work	TRUE	getting	we	doing	to	to	time
with	me	doing	for	and	all	didnt	a	do	understand	later
one	makes	the	the	which	the	have	bit	first	triangles	we
another	things	work	project	is	work	time	more	look	and	cooperated
we	easier	to	We	FALSE	done	to	I	up	hoe	very
work	to	control	use	and	We	group	just	some	to	well
a	understand	the	newspaper	that's	have	up	told	references	build	learn
lot	rather	assignments	and	what	was	out	each	for	strong	to
and	than	of	magazines	we	we	of	other	bridge	bridge	cooperate
hard	just	the	as	need	don't	class	what	on	did	much
to	learning	project	our	to	really	we	to	the	a	better
complete	for	My	technology	sell	know	assigned	do	internet	draft	texting
the	other	bridge	tools	a	what	task	Worked	figure	of	facebook
work	people	making	We	product	should	I	on	how	what	and
for	we	skype	in	specific	the	work	communicating	class	shapes	project
together	the	use	for							

Figure 4. Frequency of word use in class 1 group 4.

Do	group	we	we	our	our	our	things	class	put
all	our	have	our	not	something	about	group	used	each
group	computer	hard	up	easy	our	our	build	the	member
job	it	time	and	decide	the	project	had	internet	a
that	help	to	made	what	binder	so	trouble	gave	job
your	me	glue	group	model	we	we	meeting	us	we
assigned	a	group	group	was	also	can	outside	our	were
make	lot	popsicle	work	going	said	learn	of	on	discussing
your	our	stick	was	group	every	how	class	how	the
work	we	group	done	look	group	to	We	to	plans
complete	do	group	on	like	bring	build	all	build	together
group	our	of	time	we	an	the	managed	bridge	during
doing	best	people	we	all	our	project	group	decided	class
it	that	that	split	agreed	the	trouble	control	to	put
on	we	make	the	on	home	figuring	time,	meet	work
time	can	five	work	one	we	group	we	at	together
we	we	books	we	thing	used	what	agreed	one	give
use	our	our	used	we	our	to	two	place	also
computer	do	we	the	all	internet	build	people	work	our
we	our	think	computer	managed	it	our	do	independently	outside
copy	work	that	our	group	helped	their	bridge	then	of
group	at	we	information	control	us	was	we	gave	our
picture	group	can	showed	time	group	group	all	us	of
of	right	beat	me	group	time	them	that		

Figure 5. Frequency of word use in class 1 group 5.

I	the	also	messes	didn't	what	we	having	job	and	by
don't	work	our	up	really	needs	used	everyones	we	some	one
think	but	phones	we	have	to	our	support	just	phone	everyone
we	we	to	split	any	be	laptops	due	help	made	in
managed	didn't	contact	up	difficulties	done	computers	dates	each	it	the
so	get	each	the	when	first	for	and	other.	easier	group
well	to	other	work	working	debated	research	communication	All	and	work
because	finish	helped	among	on	and	and	with	four	easier	tougher
we	the	me	all	this	agreed	organization	all	group	to	tell
didn't	project	to	the	project	on	communicating	group	members	understand	us
get	we	realize	members	by	what	through	members	had	very	how
to	had	that	difficult	going	to	texts	Help	each	well	to
present	made	if	time	on	make	and	each	of	we	build
and	use	one	deciding	google	others	google	other	our	all	bridge
finish	of	person	what	drive	were	drive	knowing	own	worked	organized
we	laptops	messes	our	and	researchin	not	they	parts	well	tasks
completed	for	up	invention	making	and	being	are	to	together	computer
most	our	the	should	a	doing	completely	doing	build	did	one
of	research	whole	be	document	other	organized	a	used	assignments	good
and	group	we	regarding	things	and					

Figure 6. Frequency of word use in class 1 group 6.

Assign	we	to	some	kind	to	work	build	and	doubts	our
everyone	used	build	needs	of	make	on	we	we	in	bridge
a	a	the	in	invention	the	the	check	all	making	math
job	computer	bridge	the	because	bridge	day	all	take	it	activity
to	to	we	world	some	model	that	the	turns	used	made
do	research	all	we	inventors	the	you	work	the	google	us
also	what	helped	didn’t	invent	we	give	and	bridge	docs	realize
help	are	the	have	it	can	me	see	some	images	how
construct	some	invention	a	I	know	we	if	of	to	math
the	needs	and	design	think	triangle	use	they	us	create	can
invention	in	some	to	hands-on	is	computer	are	contributed	our	help
we	the	people	build	is	very	for	done	to	powerpoint	create
worked	world	did	the	very	stable	this	we	all	give	out
together	the	the	bridge	important	Keep	project	did	the	us	bridges
and	hands-on	worksheets	it	like	the	we	all	ideas	idea	more
split	activities	we	was	in	assignmen	know	each	on	of	stable
up	helped	didnt	hard	my	organize	what	assignment	creating	how	we
the	me	know	to	project	I	bridge	as	it	we	discuss
work	gain	what	think	we	finish	should	a	we	can	on
how	skills	were	what	have	the	we	group	have	create	participating
work	to	it	stable	string	all	part	making	and	in	getting
done	create	more	and	we	took	on	it			

Figure 7. Frequency of word use in class 2 group 1.

We	that	hands	I	on	a	research	we	and	lot
did	was	and	believed	learning	individual	about	first	balanced	on
nothing	hard	finish	that	activities	task	bridges	discuss	by	how
in	I	our	group	showed	in	and	that	brainstorming	stable
the	challenges	project	bridge	more	order	tips	what	we	we
invention	make	group	made	of	to	to	kind	already	had
project	impossible	technology	me	an	do	make	of	know	to
improve	to	activity	understand	idea	group	our	bridge	about	make
our	be	helped	our	on	project	bridge	are	it	it
ability	possible	to	well	creating	easier	stable	we	group	showed
I	hands-on	understand	because	our	our	and	gonna	everyone	us
try	helped	math	we	Our	was	stronger	do	a	how
to	me	concepts	use	group	good	than	what	certain	difficult
make	a	because	SSS	managed	our	others	does	role	building
done	lot	we	SAS	group	bridge	It	it	everyone	the
about	to	can	to	assignments	is	helps	look	participated,	bridge
our	understand	type	make	of	stable	us	like	group	was
group	group	in	me	group	and	to	and	ideas	we
bridge	math	internet	realize	project	balance	connect	how	the	group
project	concepts	and	much	by	computer	the	to	interactive	our
I	because	help	clear	assigning	we	bridge	make	worksheets	ideas
challenge	we	me	and	all	use	to	it	help	we
bridge	use	to	more	the	our	math	more	us	did
but	our	understand	hands	members	to	concepts	stable	a	not
work	out	of	class						

Figure 8. Frequency of word use in class 2 group 2.

Our	it	on	my	docs	more	technology	invention	the	project	and
group	for	what	members	and	of	discuss	where	bridge	I	it
managed	researching	our	are	Microsoft	an	how	it	we	help	shape
the	technologies	invention	participating	powerpoint	idea	we	should	complete	to	in
assignments	that	gonna	making	used	on	should	be	our	decide	the
of	we	be	everyone	google	how	create	struggle	individual	what	class
the	used	look	take	images	we	it	tapping	work	kind	Everyone
project	are	like	a	so	create	of	the	first	of	had
by	cellphones	after	part	that	out	make	box	then	bridge	a
being	it	that	of	we	activity	it	We	work	to	job
organized	helps	on	each	could	realize	more	work	together	make	to
and	us	how	assignment	have	how	usable	together	for	and	do
focused	to	to	we	some	formulas	not	with	group	I	and
It	be	answer	would	ideas	are	contribute	the	work	make	everyone
was	more	the	not	on	used	ideas	assignments	we	the	contributed
good	familiarized	driving	be	how	each	struggles	and	use	angle	and
we	with	question	able	can	had	in	then	are	for	finished
did	the	the	to	create	a	creating	we	internet	it	their
our	project	cooperation	finish	our	part	it	talk	google	we	work
best	we	because	on	bridge	in	such	about	and	discussing	on
computer	first	not	time	made	creating	as	how	powerpoint	how	time
we	think	all	used	us	and	putting	to	for	to	we
use	brainstorm	of	google	have	incorporati	the	make	this	make	use
some	do	and	help	used	of	did	find	bridge	some	to
people	the	some	with	computer	bridge	research	different	worksheets	to	bridge
to	types									

Figure 9. Frequency of word use in class 2 group 3.

We	go	group	got	task	giving	to	they	to	help	completed
worked	on	complete	every	we	us	come	were	build	me	on
together	google	everything	assignment	completed	a	up	suppose	everything	by	time
as	It	it	completed	all	better	with	to	was	completing	it
a	help	went	had	the	understand	something	do	completed	our	went
group	me	out	trouble	worksheets	of	that	on	of	bridge	out
to	to	good	on	that	what	was	time	what	project	good
find	improve	completed	what	that	our	not	computers	own	idea	everyone
information	for	the	to	helped	finished	invented	phones	tasks	completing	completed
completed	doing	work	invent	us	product	yet	ipads	and	the	what
all	the	on	we	a	should	Someone	popsicle	working	project	sure
worksheets	work	time	gave	lot	look	made	sticks	together	by	everyone
and	we	computer	everyone	we	like	sure	and	in	our	was
find	complete	flashlight	a	used	our	every	glue	class	creation	on
material	all	and	goal	phones	group	assignment	hands-on	trying	everyone	activities
we	the	CD	and	and	worked	was	activities	invention	leader	helped
gather	worksheet	helped	had	computers	on	finished	was	by	to	us
information	kept	us	a	hands-on	their	help	not	building	make	with
together	track	complete	group	our	invention	our	what	we	use	computer
and	of	make	the							

Figure 10. Frequency of word use in class 2 group 4.

Finish	all	individual	help	of	group	to	the	SAS	and	activity
the	the	work	them	our	manage	understand	bridge	AAS	finish	help
assignments	work	the	to	invention	because	the	because	SSS	our	me
on	and	we	decide	because	our	math	we	improve	project	understand
time	see	talking	what	we	group	concepts	have	our	when	the
check	if	about	going	don't	doesnt	because	to	ability	we	math
all	they	the	to	have	understanc	when	make	try	do	concepts
the	done	assignment	make	enough	about	we	strong	to	this	when
work	we	later	and	time	project	do	bridge	make	project	we
and	don't	I	give	one	my	this	but	done	group	do
see	know	work	example	of	group	project	that	about	was	this
if	what	individual	for	our	did	we	was	our	manage	project
it	invention	for	my	teammate	really	use	hard	group	because	we
done	to	the	teammate	did	best	if	try	bridge	they	learn
we	build	work	we	not	and	and	to	project	dont	SSS
use	some	then	discussing	bring	complete	then	make	hands-on	get	SAS
phone	of	we	about	the	paper	my	impossible	help	how	ASA
for	the	did	getting	stick	my	group	to	me	to	hands-on
this	group	the	all	for	group	discussed	possible	a	do	help
project	members	teamwork	the	bridge	use	our	that	lot	it	me
we	dont	in	work	to	computer	invention	was	to	I	a
can	do	group	done	class	to	for	hard	understand	use	lot
learn	anything	we	for	when	work	what	Group	the	my	gather
more	we	use	project	we	on	we	work	math	phone	information
about	separate	internet	in	do	this	are	and	concepts	to	contact
the	or	google	class	assignments	project	gonna	everyone	because	work	others
project	divide	for	we	of	hands-on	make	do	we	on	how
we	the	our	cant	the	activities	it	their	use	this	to
can	work	group	build	project	help	challenges	own	our	project	do
collect	into	I	one	my	me	for	work	hands	hands-on	presentation
find	me	doing	work	to	how	learn	better	project	it	get
materials	to	the	as	make	to	more	everyday	for	we	group
it	improve	work	a	the	build	and	help			

Figure 11. Frequency of word use in class 2 group 5.

We	example	jackets	our	bad	we	we	to	the	know	was
are	for	and	class	because	were	did	do	things	more	the
doing	my	tape	and	its	not	our	we	together	about	manage
assignments	teammates	it	we	hard	cooperatin	best	put	and	the	and
individual	we	made	completed	to	and	to	a	we	triangle	control
then	discussing	it	the	make	a	do	lot	have	and	monitor
talk	about	more	powerpoint	a	lot	our	of	agreement	how	just
about	what	easier	and	invisible	of	work	glue	needed	to	do
it	invention	for	present	box	things	we	we	to	make	some
later	got	me	although	we	we	did	made	be	it	work
we	to	we	it	do	need	not	stick	done	more	what
working	make	got	was	the	to	meet	bridge	I	stable	I
individual	none	the	not	worksheets	do	up	very	did	we	need
and	challenges	jobs	perfect	together	by	it	stable	everything	other	explain
working	in	we	we	but	myself	was	its	that	member	what
teamwork	invention	want	made	the	Just	good	very	was	we	is
together	project	we	a	ppt	did	in	good	assigned	never	invisible
we	challenge	didnt	box	was	what	our	bridge	calculators	see	box
using	is	meet	model	made	it	group	helps	was	it	even
computer	how	up	to	by	was	I	us	used	before	though
to	to	its	to	everyone	the	work	together	most	present	its
research	make	good	decide	a	bridge	and	led	stable	it	not
it	bridge	because	what	job	which	give	lights	in	the	really
help	stronger	we	going	do	is	think	very	its	agreement	invisible
them	assign	made	to	everything	the	I				

Figure 12. Frequency of word use in class 2 group 6.

Observations

Participants in the PBL curriculum were asked to answer the two authentic questions:

1. How can Engineers use triangles to construct strong, stable and safe structures?

2. How do you use math statements to advertise a new product or invention?

In the process of answering the authentic questions, my students created and built artifacts that reflected the planning, group collaborations, technology use and hands-on experiences. They used popsicle sticks to build triangular model bridges to demonstrate their understanding of bridge design. The students also created miniature triangular and square shaped models with toothpicks and identified the structural strength of both shapes. Furthermore, students used logical mathematical statements to create a persuasive advertisement for a newly developed invention. Their planning processes included developing a storyboard for their final presentations, a blueprint for their bridge model and an advertisement for a newly invented product.

My students also created a project presentation through the use of PowerPoint and drew blueprints, triangular diagrams, and scale diagrams of their bridge model. Part of the project's requirements was for students to create artifacts that represent the planning process (miniature models, blueprints, and storyboards). The bridge model was to have triangular shapes and a pathway for a model car to pass through. Their bridge models were evaluated only by me to determine if bridge requirements were met and tested for bridge strength. The new invention was evaluated to test if conditional logical mathematical statements were used. Additionally, the new product must be original and provide a useful and purposeful benefit to people.

Each group presented their completed project to the class and explained the process of their work. Each student completed a project exam. These examinations concluded the final project stage by assessing students' learning and assessing their ability to connect their learning with their projects to a real-world issue. The goal of the presentations was for students to synthesize their learning and communicate that knowledge to their peers.

I observed three categories of student work behavior when students (a) began a new task; (b) were working within their groups; (c) were discussing project work. Additionally, subcategories within each of the three categories were observed whether all, most, some or few of the group members were actively involved and participating in the group activities (see Figure 13 to Figure 18).

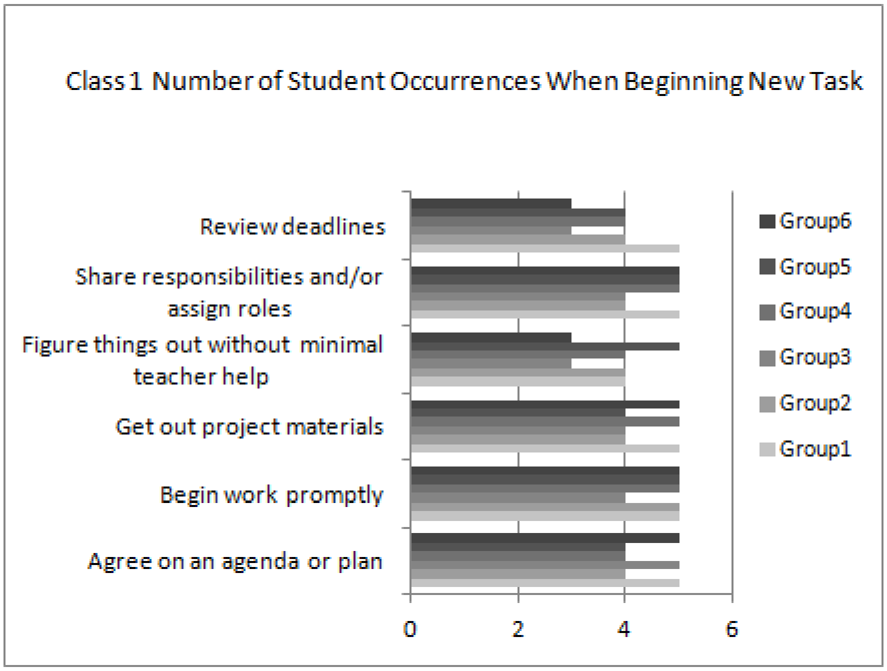


Figure 13. Observations of class 1 student work behavior when beginning a new task.

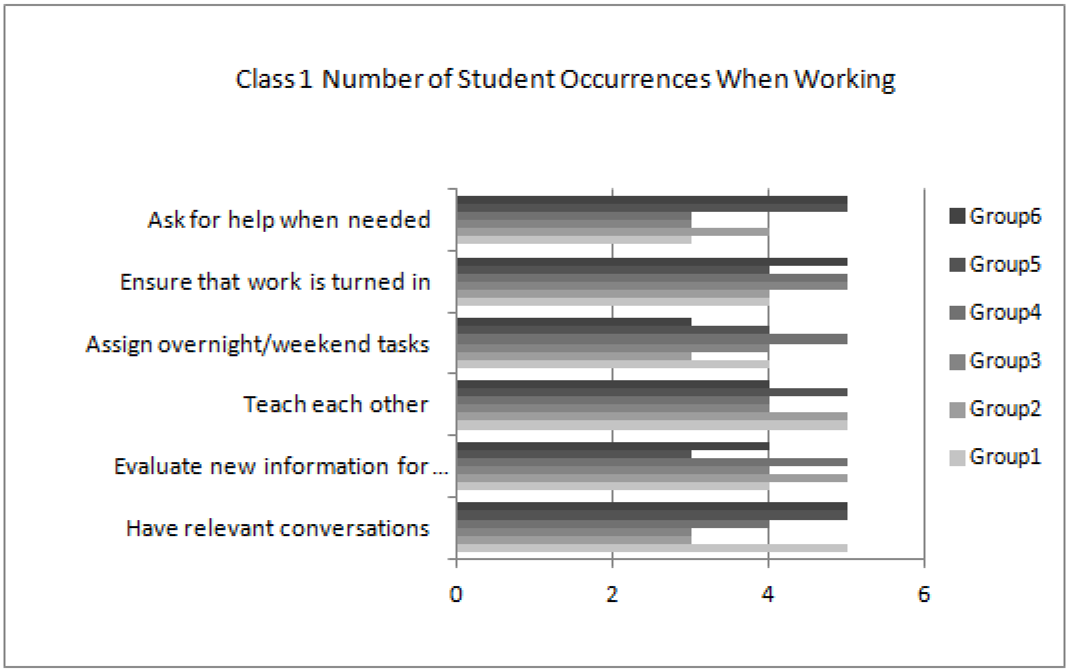


Figure 14. Observations of class 1 student work behavior when working.

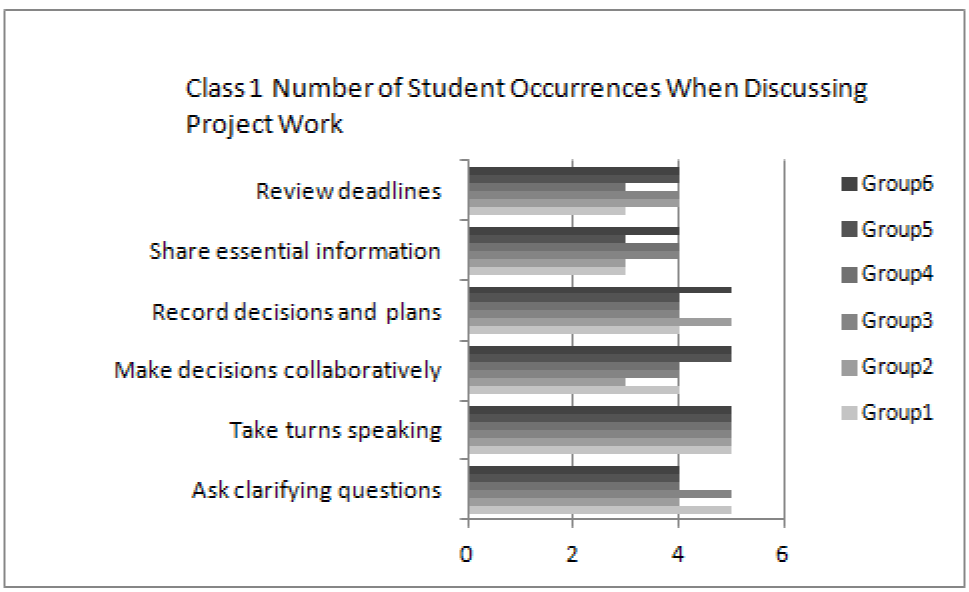


Figure 15. Observations of class 1 student work behavior when discussing project work.

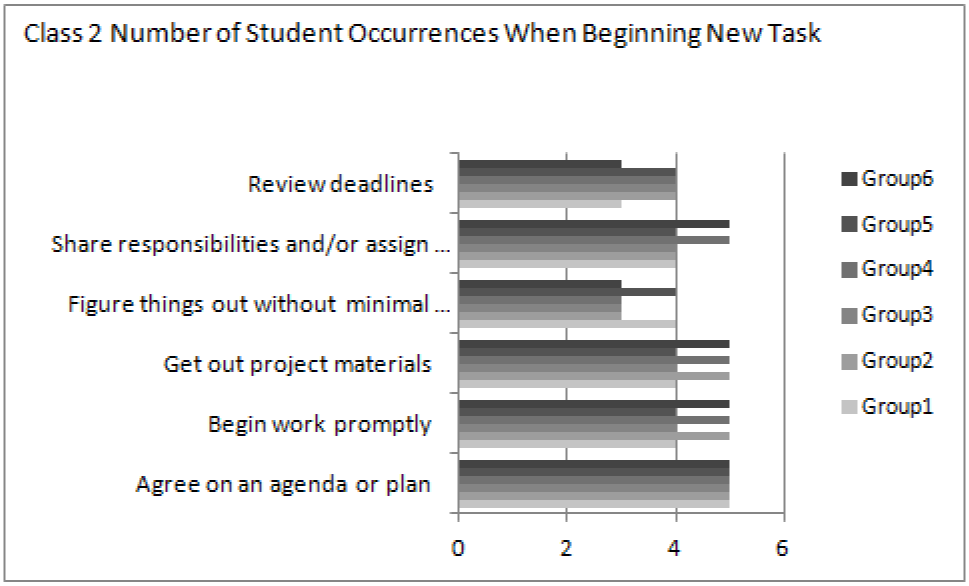


Figure 16. Observations of class 2 student work behavior when beginning a new task.

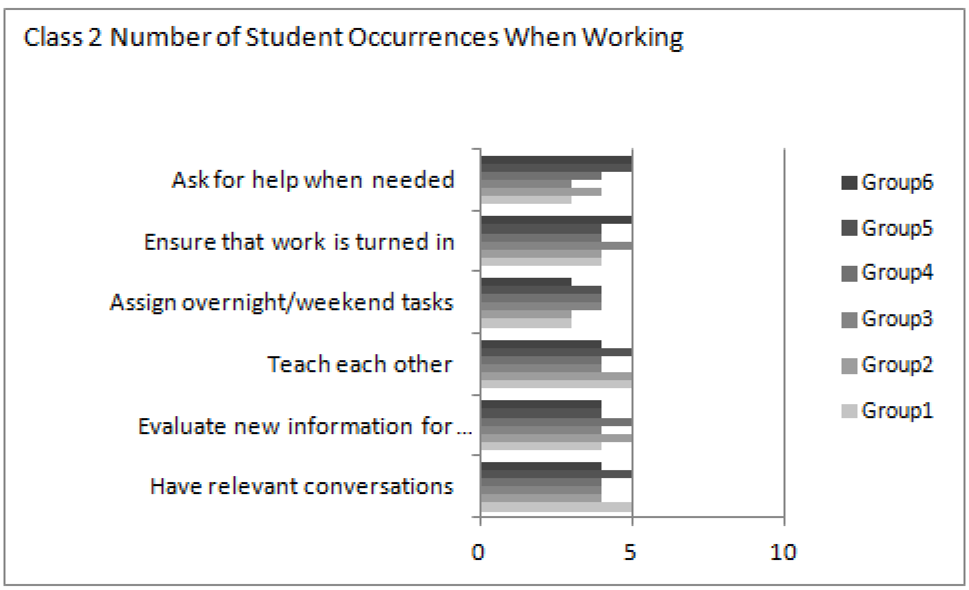


Figure 17. Observations of class 2 student work behavior when working.

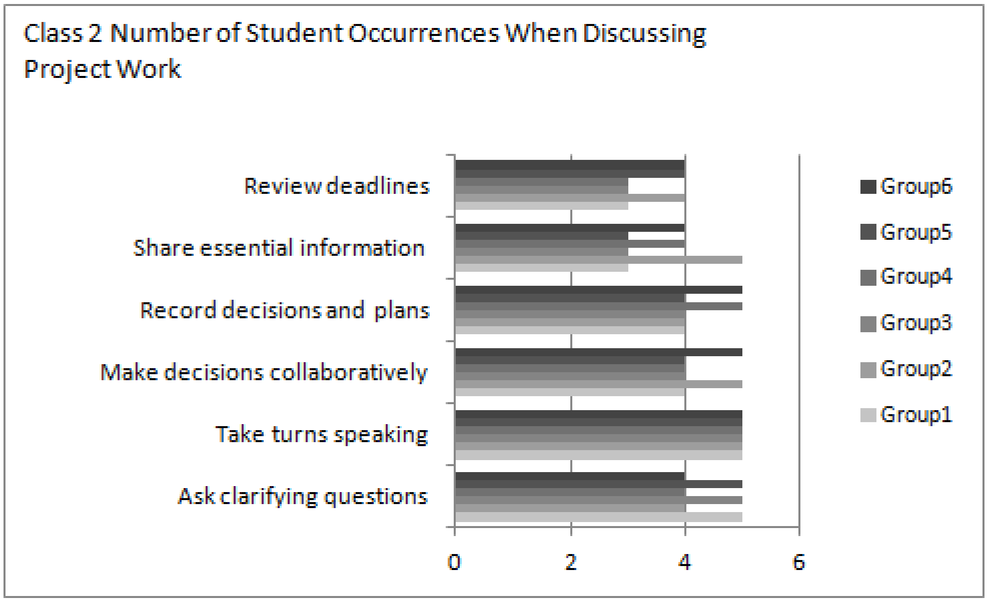


Figure 18. Observations of class 2 student work behavior when discussing project work.

Findings and Results

Final project artifacts, along with reflections, transcribed interviews, and observations support the findings in this study. The findings were categorized into general themes.

Project Design

During the projects' presentations, my students expressed their desire to continue making improvements to the bridge designs and the invention products. The experience of the improvement process to the final product was recognized as beneficial to them. My students' comments revealed a great desire to improve the quality of their bridge models and the product of their new invention. They also commented on their experiences with adjusting the design and working through the different stages of planning.

Project Strategies

In this study, groups developed strategies to answer the authentic questions, design the model of the bridge, and create a newly invented product. The students had a total of three hours of planning time in this PBL curriculum which gave them adequate opportunity to develop strategies for their projects.

The group's project design goals focused on the components of measurements, scales, blueprints, and searches for advertisement and newspaper articles. The exact details of my students' designs appear in the planning blueprints, storyboards, and final presentations. They answered each project's authentic driving question and included project development strategies that addressed a real-world situation.

The final group presentations of two different projects described the requirements for 1) designing a bridge model as an alternative to commuting between the islands and 2) a new invention product that will help people with the completion of daily tasks more easily. The groups also considered the needs of the people who drive across bridges and the extent to which their new product would be useful to the community. The groups also considered the professional appearance of their designs, the strength of their bridge model and the usefulness of their new invention. The groups provided rich descriptions of project design developments in their presentations. One student said of the project design development, "We thought the bridge model should be strong and long enough to cover the distance for people who will be travelling between the islands." (Class1, Group 4 Student)

Below are sample comments of a student identifying the needs of the people and audience of the bridge model and the new invention product. The development of the project ideas helped this group with specific content in mind with the design:

- "We want to advertise our new invention product by meeting the needs of people." (Class 2, Group 3 Student)
- "We wanted a bridge that will allow cars to travel in both directions." (Class 1, Group 5 Student)

These statements made by group members describe how the approach to the design of the bridge model and new invention product, based around organizing geometry content was determined most useful:

- "We know that it is very expensive and cost a lot to travel between the islands, but must be strong enough to hold the travelling cars. We learned in class that triangles are the strongest shape. So we used triangles to build our bridge." (Class 2, Group 1 Student)
- "Our advertisement should be clear and understandable. We need to use logical math statements so that people know what we are saying." (Class 2, Group 2 Student)

A student from Class 1 Group 1 described their design and ways the group solved a variety of specific problems. Their idea was derived from a problem identified and then a strategy for addressing the problem with a bridge model design was developed. Another student from Class 2 Group 3 derived a problem from peoples' daily needs and found a solution to addressing the problem with a new invention product.

Problem Solving

A variety of approaches used by the groups in the two classes addressing the authentic questions were revealed in the final projects through the planning blueprints, storyboards, videos, artifact, content knowledge, structural models, technology use, hands-on experiences and collaborative approaches. Demonstrated by the completed bridge model blueprint of Class 1 group 3, there is a distinct focus on the design blueprints and incorporation of triangular shapes in the bridge. For Class 2 Group 2, there was a focus on using clear logical statements to generate an influential effect with the advertisement of their product. For Class 1 Group 2, the design of their bridge included triangular shapes and an enticing commercial to promote the product. Class 2 group 5's approach, included the use of geometric concepts learned in class and the building resources that were made available to them. Class 2 Group 3 included an internet search for bridge models and technical blueprint drawings. Class 2 Group 4 created a miniature model with toothpicks and tested the strength of the structure with textbooks. Through a group discussion process, Class 2 group 1 used logical statements to create an advertisement for their new invention product.

The multiple designs and methods used by my students to address the authentic questions illustrate the enthusiasm to find solutions and imaginative ways to appeal to their audience. The use of authentic questions in a project focuses students' attention to real-world issues and allows them to share and find innovative solutions to different issues. The multiple solutions to real-world issues can be attributed to hands-on and technology integration experiences.

Hand-On Approaches

My students in both classes described in their presentation, their experiences with their hands-on approach to building the bridge. They described the detailed use of popsicle sticks as well as the type of glue used to build the bridge. There were also descriptions of the link between the structural strength of triangles and the way of how bridge model blueprints should be drawn. Students in Class 1 Group 3 stated, "We wanted to use triangles in our bridge design so it will be strong enough to hold a lot of weight. So our blueprint should be drawn with a scale and with triangular shapes in it."

The following statement describes the student's description of the bridge making process with blueprints and the importance of incorporating triangles into their bridge model. The student stated, "The bridge model can only be built with eighty popsicle sticks and must include a pathway for cars to travel through. One person should build the bottom and the sides." (Class 2 Group 3)

This statement describes the groups focus on modeling a real-life bridge with the focus of working together as a team.

- "We must create an invention that everyone will want. To do this, we must give clear statements so everyone will understand what we are trying to sell." (Class 2 Group 1)

- "We divided up the work to search for articles in newspapers and magazines that show logical statements." (Class 1 Group 1)

These statements emphasized a group collaboration process to understand the use of mathematical logical statements to create an advertisement.

Technology Integration

Class 1 group 3 and Class 2 group 3 described in detail a variety of ways they integrated technology into their bridge model and new invention product. In the final presentations, group members described the integration of technology with the use of phones, computers, calculators, software applications such as Microsoft PowerPoint, excel, word and Google docs, iPads, and Paint.

- "We used the computers in the computer lab to search for information on types of bridges that had a lot of triangles in them. We then copied a picture of it onto the PowerPoint slides" (Class 1 Group 1 student)

The student's statement on the final presentation described how to integrate their bridge model design into a PowerPoint slide show with the use of different types of software and technology applications. This student cut and pasted pictures of bridges onto PowerPoint slides. Group members in this student's group worked alongside on the PowerPoint slides simultaneously via Google docs.

"Our group was able to complete a lot of slides and written reports through google docs." (Class 1 group 4 student)

The statement is a description on the choice of a group to use a software application to complete their project tasks. To do this each member had to have a Google account. Students who do not have a Google account signed up for one.

- "I just searched for bridge photos on my phone." (Class 1 group 3 student)
- "The use of the internet to search for logical mathematical statements helped me to understand what a conditional statement is." (Class 1 group 6 student)

Groups integrated a variety of technology into two different projects 1) a bridge model and 2) a new invention product. Requirements of the new invention creation included having a handout to advertise their created product such as a brochure or flyer or advertisements which required my students to use the software applications Microsoft publisher. The requirements for the bridge model presentation included the explanations of where triangles may be located on their bridge design. To illustrate the location of these triangles, some of my students have chosen to take picture of their bridges with their own digital cameras. My students then edited these photos. Each group had the choice of how they wanted to integrate technology into their presentation. "We used our phone to make a video of our new invention product." (Class 2 group 2 student) This student made an advertisement through the use of a phone for ease and convenience other than the use of a video camcorder. This is an indication of the increase in familiarity, the increase use, and advance level of students' knowledge in using technology.

Collaboration

In this study, word use was counted through interviews and reflections. Words that related to groups such as processes of group work or groups working together were referenced. Examples of these words are "we," "our," and "group" (see Figure 1 to Figure 12). Student interviews showed the presence of these as the common words. In Class 2, Group 2 "5%", "Class 1 Group 3 "6%", Class 1 Group 2 "6%" and Class 1 Group 5 "8%" of the most dominant words appeared than the other groups in both classes, which had less than 5% each. These four groups described in their presentation of how efficient and effective their groups were working together. Group members and peers in these groups indicated that they worked cooperatively and made efforts to complete project tasks. Students' reflection showed another group of words appearing as the most common. These include "all," "together,", and "everyone" which accounts for 9% of the most dominant words in the interviews (see Figure 19 and Figure 20).

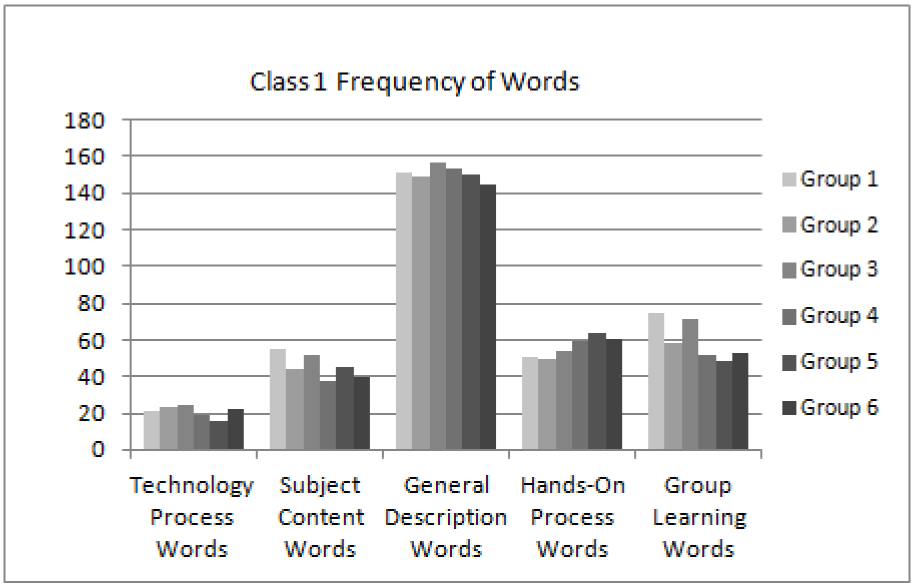


Figure 19. Frequency of words in class 1.

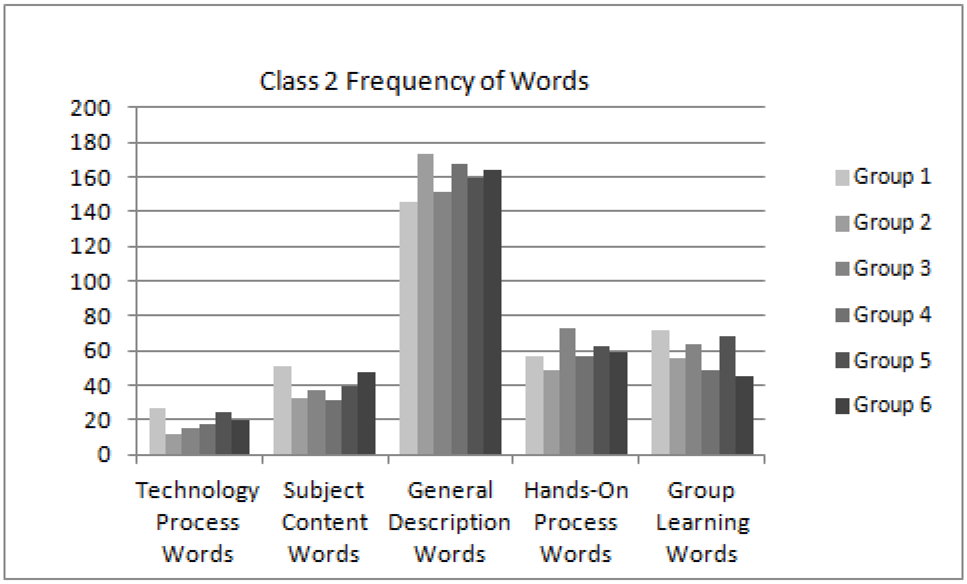


Figure 20. Frequency of words in class 2.

Communication between group members during group working sessions was prevalent and was displayed informally. In the presentations, group members were able to explain their duties and job requirements. The explanations in their presentations also included the frequent use of the words “all,”, “together,” and “everyone”

In the group presentations, the experience of working collaboratively with group members was described. The students explained how they managed and worked around their schedules to meet the requirements of the project. Group members explained how they adapted to the changing requirements as project requirements evolved. This is shown in the following quotes:

- “Sometimes one of our group members don’t show up to class, we just continue working, help each other with what needs to be done” (Class 1 group 4 student)
- “When one person is absent, we just divide up the work and get it done.” (Class 2 group 3 student)

As stated by a Class 1 group 4 student, the benefits of working as a group is the help that was provided to each other. This provided students with the opportunities to express their opinions and thoughts and to have a buy in to what the group is doing. As one student stated, "Working in groups helped because we can split up the work. We can get our work done faster." (Class 2 group 4 student)

The group work was divided among Class 2 group 4 members. Two students worked on PowerPoint slides while the other group members in the group worked on bridge blueprint pictures and article searches. Managing group tasks through this approach provided support for each individual for completing the main parts of the bridge model and new invention product. Another group in Class 1 also separated their task, where half of the members came up with advertising slogans using mathematical logic while the other half worked on setting up PowerPoint slides.

Hands-on Activities

Students in both classes were involved in a variety of hands-on activities. The new invention project involved scaffolding activities that included searching through newspapers, magazines and listening to radio station advertisements and articles for logical statements. The purpose of the scaffolding activities was to help guide students with the understanding of logical mathematical statements and to relate them to statements that are depicted in advertisements and commercials. After collecting advertisements in the newspaper and magazines, students were told to collaborate with their group members and share what they were able to find. The new invention project also required them to interview companies that promote new products and to ask questions pertaining to the importance of using clear logical statements with their advertisements. Students called mainland companies and gathered pertinent information which helped with the creation of their new product.

The bridge model project involved an extensive amount of hands-on activities. Students were required to interview engineers and ask questions pertaining to structural strength of triangles. To discover the meaning of the concepts in congruent triangles, my students were told to use rulers and protractors to measure the sides and angles of different triangles. Students also used cardboard pieces to construct triangles and squares. This process led them to understand the strength of two-dimensional shapes. Further, students' used toothpicks and constructed three-dimensional shapes of cubes and triangular pyramids. These processes supported their understanding of a structure's strength in two and three dimensional objects. Each of these activities helped to build more knowledge that led to the construction of a bridge model. At the end of the project's completion phase, students' bridge models were tested for their structural strength.

Technology Activities

Both projects involved technology activities. Students involved in the new invention project not only found advertisements in newspaper and magazine articles, but have used the internet to search for advertised articles. My students used Google search and typed in key words of "conditional statements", "logical statements", "advertisements" or "commercials". Students needed to have a basic understanding of what a conditional statement is prior to determining whether an advertisement that is found is logical and clear. Students also demonstrated their basic understanding of logical statements through advertisement presentations to advertise their created products. Storyboard examples researched online were used by students to help with the organization process of their ideas. As a result, a variety of storyboards, presentations and products were produced.

Students also used the internet to search for any math content taught in class which seemed confusing to them. Individual smart phones were used by my students as an alternative to a computer for information search activities. As reported by students, PowerPoint was the most used software to create presentations while Prezi was used by only two groups. My students also used Google docs as the central means to working cooperatively with their groups to edit their PowerPoint presentations. Students' presentations were transferred on to flash drives and uploaded to a computer on the day of the project presentations. Groups also created videos of their new invention with cameras and smart phones. The group's videos were taken home for editing and revising prior to their presentations. My students also used Microsoft publisher to create brochures for their new product.

The model bridge project required my students to search for information regarding the types of bridge models in the world and narrowed their options to ones that involved triangular shapes. This project required students to draw blueprints of their bridges. Some of them used a computer while others used their phone to search for bridge blueprint examples. The project required students to construct a bridge model that would connect the two islands of Oahu and Maui. Students searched through the internet for this information and created a scale drawing of their bridge model.

For group presentations, students had the choice of creating videos, PowerPoints, or Prezi. Completed presentations were transferred onto flash drives and uploaded to a computer on the day they were scheduled to share their projects. Computers were brought to class by the students to display the variety of animations and sound effects in their group's PowerPoint presentation. Cameras were used to take pictures of bridge models and were displayed on PowerPoint slides.

These pictures showed the importance of the triangles in their bridge models and in answering the projects driving question.

Learning Behaviors

The groups that participated in the projects expressed a sense of satisfaction and enjoyment with their work. The opportunity for students to work with their team members gave them a sense of importance and belonging. Groups expressed that they worked well together which made the learning process much more enjoyable. Some quotes from some group members follow:

- "We had a great group. Each member in the group contributed and did their fair share of their work. I would like to work with this group again." (Class 1 Group 4 student)
- "It was much easier to work with my group members. Although our groups were randomly chosen, I knew many of them from my other classes." (Class 2 Group 1 student)

Students expressed the importance of being able to work with each other as the key to completing the projects. The importance of good communication was also stressed as a key factor in completing many of the projects' tasks and activities. Working cohesively through discussions, sharing of information, division of work and participation were the important ingredients of the learning process in the project.

- "The brainstorming activities done by the groups were helpful in deciding ideas that need to consider when building the bridge." (Class 2 Group 5 student)
- "We divided up the work. Each person was responsible for working on their part. We then came together to discuss what we needed to do next." (Class 2 Group 2 student)
- "We had a PowerPoint presentation in Google docs, everyone logged in and helped with putting things on top of it." (Class 1 Group 2 Student)
- "Each person had an area where they were good in, one person did the pictures, one person did the sounds and one did the animation." (Class 1, Group 3 Student)

Many groups explained that group work was evenly divided. This process made the work more manageable and the group's ability to work with each other more cohesive. Being able to work together as a group is an important skill as it supports students' ability to learn better.

Group Challenges

The students also identified the challenges of working in groups. Two groups, Class 1 group 4, and Class 2 Group 2 explained their concerns that groups with different sizes, skill levels, personalities, and work styles are challenges. These challenges contributed to group members' ability to work efficiently and effectively.

- "Our group had only 4 students compared to other groups. We had a student that did not show up half the time." (Class 2 Group 6 Student)
- "Some of the group members were distracted easily; they were talking about other things. I had to ask them to do their work." (Class 1 Group 1 Student)
- "One of our group members forgot to bring the materials to class. We can't work without the materials." (Class 2 Group 3 Student)

These comments made by my students show the challenges of managing an effective working group in completing assignments and tasks. These challenges added to the weight of not only completing project requirements, but managing group members' reliability, initiative, and motivation to work.

- "We had an idea of what our invention should be, but not everyone contributed and agreed." (Class 1 group 5 student)
- "Some of our group members did not show up to our afterschool meetings." (Class 2 Group 3 student)

Besides these issues, the groups had issues within of working with personality styles. Some groups had one group member doing all the work while some groups also had members showing up to class late with poor working attitudes. The issues of working personality styles contributed to the group's ability to meet the group's daily assignment deadlines.

Project Challenges

Students were asked to invent a new product which benefits people to respond to the project's driving question: How do you use math statements to advertise a new product or invention? Students needed to have a basic understanding of conditional statements. They also needed to know what invention their group would be creating. Below are sample of the descriptions of group member's experiences:

- "We need to use if-then conditional statements in our advertisement of our products, so what we say is clear." (Class 2 Group 3 Student)
- "Our group had a hard time trying to come up with an idea of an invention, but when our group came together and thought about benefits, we came up with something." (Class 2 Group 1 Student)
- "We had to look for advertisements and change them to logical statements." (Class 1 Group 2 Student)

The sample descriptions above demonstrate my students experience and challenges with the new invention project. The process of searching, collaborating and thinking deeper shows my students problem-solving initiative and goal to produce an artifact that is of quality.

- "The time we were given was too short. If we had more time our invention would have been better." (Class 2 Group 4 Student)
- "We had so many things to do; I think we could have managed our time more wisely better next time." (Class 1 Group 5 Student)

Many groups expressed the concern of time constraints being a factor of doing a better job with their projects.

They created an artifact to address the project's driving question of how can engineers use triangles to construct strong, stable and safe structures. In the process of creating the artifacts, Students' had to understand the definition of angles, blueprints, scale factors, congruence of triangle, and the use of protractors and rulers. Below are samples of the descriptions of group member's experiences:

- "I had idea no idea of how to use a protractor, but someone in the group showed me how." (Class 1 Group 5 Student)

- "I did not know how to tell if two triangles are the same, until I started to measure the sides and angles of the triangles." (Class 2 Group 4 Student)

- "Our group had problems with what a blueprint is, but we searched for examples on the internet and showed our group." (Class 2 Group 6 Student)

As shown above, my students' experience working in groups helped them with using basic tools and with understanding of basic geometrical content. This experience helped my students to understand and develop collaboration, and technological skills.

- "We were limited on time to meet and discuss. Our group members could not meet outside of class." (Class 2 Group 3 Student)

- "I feel this project was very rushed. We needed more time" (Class 1 Group 1 Student)

Members in this group expressed the concern of time constraint as being a factor of doing a better job with their projects.

Assessing Final Products

Project Rubric

Many groups created a bridge model and a new product that addressed the components of the project's rubric. Addressing the project's rubric produced a multitude of presentations and artifacts. During discussions of the intended audience for their product, a variety of product artifacts emerged such as a scissors that had a flashlight attached to it or an invention of a three-in-one toothbrush that includes a toothbrush, toothpaste and a dental flosser. Below are some project experience statements made by students. These statements demonstrated their project's connection with real-world needs.

- “Our bridge model is an example of how a bridge should be built to connect Oahu to Maui. It meets the needs of users.” (Class 1 Group 3 student)

- “The invention of the accu scissors help people cut things in the dark when there is no light available.” (Class 2 Group 2 student)

Groups addressed the authentic question of the projects by creating products which meets the real-world needs of users.

Problem Solving

All groups explained their methods and strategies for group discussions and problem-solving. Hands-on and technology activities were the two main areas which were developed and heavily incorporated into the projects. These two areas helped my students to complete the projects in a more timely and consistent way.

The two projects helped students to develop skills in the areas of problem solving, group collaboration, higher order thinking, and understanding and use of technology. The projects required my students to create authentic and original artifacts and demonstrate the requirements of time, effort and knowledge. For example, one student shared, “We looked up samples of bridge models on the internet, but some did not have many triangles in them. We thought about creating our own bridge model that uses the triangles.”

The students in groups looked up the theory and structure of triangles to address the need of bridges. The creation of a new invention and bridge model were the goals of the tasks and requirements of the project.

Task Factors

The tasks of the project were driven by the goals to answer the project’s driving question. Groups created sophisticated and creative artifacts and described the steps and processes taken to address the questions of the project. Groups met the requirements of the assessments.

Class 1 group 1, 5, and Class 2 group 6 developed an invention that met the needs of the user by creating a two sided sports bag, binder clip pencil holder, and a one piece clothes hanger that required the involvement of both hands-on and technology activities.

All groups in class 1 and 2 built bridges that met the requirements of the user and the project through individual scaffolding activities. Each group designed their own bridge model to address the projects driving question.

Level of Success

Students' level of success in this project was dependent upon the group's ability to create an artifact that addressed the project's driving question. Other components included the incorporation of technology and hands-on skills to the production of their product. The final project also included math content knowledge, organizational skills, collaboration efforts, higher order and critical thinking skills, and task management.

Through the process of working on the projects, students became aware of the importance of geometric figures in the buildings and structures. They also expressed the understanding of how logical clear statements influence the effectiveness of an advertisement. The experience of learning geometric concepts through internet searches and hands-on approaches was expressed as challenging, but also rewarding. As stated by students participating in the projects, the benefits derived would have lasting effects on applying math skills to everyday needs of the society.

- "Hands-on has helped because we are actually getting experience and information that we know is correct." (Class 2 Group 4 student)
- "The hands-on activities were helpful because it showed me how the math concepts work." (Class 2 Group 1 student)
- "The hands-on activities helped to make a clearer visual connection with what we learn in class to a real-life problem." (Class 1 Group 4 student)

- “Technology helps with learning because theres a lot of stuffs about the project that can be searched on the internet.” (Class 2 Group 3 student)

- “Technology gives you more information and it shows you pictures of what you searched right away.” (Class 2 Group 5 student)

Students expressed a sense of satisfaction in building the bridge models and in creating new invention products. Greater excitement developed as they tested the strength of their bridge model along with their classmate’s models. Students were also enthusiastic to show off their product for everyone in the world to see.

- “I know my bridge model can hold at least 15 textbooks because there are a lot of triangles in the bridge model.” (Class 2 Group 6 student)

- “I uploaded my invention presentation on YouTube for everyone to see. Next years’ students can see what was done.” (Class 1 Group 2 student)

The deep involvement and interest of my students in projects supports the idea of connecting real-world situations with classroom concepts.

- “When and what is the next project that we will be working on?” (Class 2 Group 3 student)

- “I did not know that bridges involved math. Now I know why triangles are the most strongest shape.” (Class 1 Group 4 student)

- “I really liked this project; I would add more popsicle sticks next time.” (Class 1 Group 5 Student)

These projects by students incorporated different technology and hands-on activities to support the learning of mathematical concepts. Students indicated issues within their groups with agreements on bridge designs and invention product ideas. Many groups expressed that managing the steps of a project to its completion stage required an enormous motivation and cooperation of group members.

Paired Sample t-Test

A paired sample t-test was conducted to compare students' post-test scores in a PBL and NonPBL instruction classroom which utilized two projects. Project one was an invention and project two was building a bridge There was a significant difference in the invention scores for students' post-test with no PBL (M=10.53, SD=3.83) and post-test with PBL (M=18.56, SD=8.50) conditions; t(29) = 5.505, p = 0.000 as indicated in Tables 2 and 3. There was also a significant difference in the building a bridge scores for students' post-test with no PBL (M=11.90, SD=5.39) and post-test with PBL (M=23.20, SD=7.25) conditions; t(29) = 7.332, p = 0.000 as indicated in Table 2 and 4. These results suggest that PBL have an effect on students' learning.

Table 2

Post test scores for PBL and non-PBL instruction

	Class 1		Class 2		
	M	*SD*	*M*	*SD*	*t*-test
Invention	10.53	3.83	18.56	8.50	5.51*
Bridge	23.20	7.25	11.90	5.39	7.32*

$^*p < .05$

Note. M = Mean. SD = Standard Deviation. The highest score on the invention quiz was 36 out of 40. The highest score on the bridge quiz was 38 out of 40. Class 1 received PBL instruction for the bridge activity and class 2 received PBL instruction for the invention activity.

Table 3

Measures of association for comparison in post-testPBL and post-testNonPBL scores for Invention

		Paired Differences							
				Std. Error	95% Confidence Interval of the Difference				Sig. (2-
		M	*SD*	Mean	Lower	Upper	T	Df	tailed)
Pair 1	PostTestPBL – PostTestNon PBL	8.03	7.99	1.46	5.05	11.02	5.501	29	.000

Table 4

Measures of association for comparison in post-testPBL and post-testNonPBL scores for Bridge

		Paired Differences							
				Std. Error	95% Confidence Interval of the Difference				Sig. (2-
		M	*SD*	Mean	Lower	Upper	T	Df	tailed)
Pair 1	PostTestPBL – PostTestNon PBL	11.30	8.44	14.45	8.15	14.45	7.33	29	.000

Overall Themes of Study

In this study, the importance of task management, group dynamics and discussions, and leadership roles to complete projects and learn new skills appeared as central themes. These themes appeared in all of students' descriptions in their reflections, and interviews. The reflections and interviews showed the importance of managing the tasks of the project more effectively, having better group discussions and group dynamics. Hands-on and technology activities themes were also stressed by students as essential components to the understanding of subject content and to the completion of projects. These factors affected each group in a variety of ways. My students stressed the importance of these factors as being the key components to the completion of the project in addition to improved communication, group interactions, and understanding the content.

The focus on math content and group interaction activities were evident throughout the working stages of the projects' period and became important themes. As students worked towards the completion of their projects, new project requirements evolved requiring them to adapt and change to the demands of the project. Students' reflections and interviews revealed the importance of the group's ability to work together to complete the requirements of the project. The flexibility of group members to adjust and to meet the needs of the project also indicated their willingness to work with each other.

The final project presentations by the groups in the two classes showed a variety of approaches to answering the projects' driving questions. A variety of multimedia tools, technology and hands-on activities were used to complete project requirements. Each group designed and built their invention and bridge model in different ways to address an authentic real-world problem thorough the understanding of math content and group activities. The projects involved the understanding of math concepts, hands-on and basic technology skills such as scale and angle measurements, logical mathematical statements, triangle congruence, and searching for information on the internet. Students indicated a sense of satisfaction in learning through a project-based approach.

Summary

This study indicates that there were a variety of group approaches and satisfaction levels in the use of technology and hands-on activities in a project-based learning curriculum. Technology and hands-on activities assisted students in content comprehension and task completion. Each group designed and built a bridge model and new products with the use of technology tools and hands-on activity skills. The themes that evolved emphasized the importance of effective communication, group dynamics, and task management within the groups. The continuation of group discussions and collaborations are key components that contributed to successful project outcomes.

Chapter five will discuss the analysis of these results with conclusions drawn and implications identified.

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

This chapter provides a summary of results, conclusions, and recommendations. The chapter begins with a summary of the main points from this study, followed by conclusions drawn, and implications for the discussion of both practice and future research. The chapter concludes with future recommendations for research.

Summary

The aim of this PBL study was to answer four research questions that related to PBL. The answers to these questions provided me with an understanding of how PBL helped students learn and how have my own teaching practice changed and evolved. The questions involved in this study were: how does the use of technology in PBL impact students' comprehension of geometry concepts, how does hands-on experience in PBL when practiced by students show an impact on students' comprehension of mathematical concepts, how does the experience of group collaborations and discussions in PBL when applied as a problem solving strategy impact students' comprehension of mathematical concepts, and what do students perceive to be the most impacting factor of PBL in learning mathematical concepts. The aim of the study was to explore the themes, experiences, and decisions displayed in the language of students as they used technology tools, participated in collaboration sessions, hands-on activities, and group work while participating in a project-based learning curriculum activities. The study was also to explore the experiences encountered by the teacher during the students' participation in the project. The language the students used during their participation in hands-on activities and with technology was analyzed and is now understood more clearly by me. The research study involved two classes of 30 students each, of high school students enrolled in a geometry class for the first semester of the 2013–2014 academic school year. The groups of students were observed for 10 classroom sessions.

The results of the research reveals the benefits of a PBL curriculum for group projects, using technology and hands-on activities found in this study were the groups' approaches to continually improve their projects. Further benefits include the appreciation for technology use by my students and participation in hands-on activities. These findings from my study are consistent with Hernadez et al's (2009) and Satterthwait's (2010) research concluding that a specific PBL strategy using technology and hands-on activity helped students learn and assist in the acquisition of geometry concepts, skills and knowledge. In addition, PBL improved my students' attitude towards learning mathematics with the use of technology tools and involvement in hands-on activities. Also the students' awareness and understanding of mathematical concepts improved as a result of their participation in PBL.

The use of key vocabulary terms by group members during project groups processes parallels Hakkarainen's (2009) idea of having small learning groups for learning, collaboration, and conversations within the group. The words used between group members indicated a process of communication in group learning and collaboration. In addition, the delegation of tasks and leadership roles were the main factors that promoted group dynamics amongst group members in the process of completing projects, a notion that is supported by Bell's research (2010) about social skills. The audio data collected during students' interviews further reinforced that these factors contributed to the groups' dynamics during the project working phases.

The construction of bridge models and the invention of new products by groups met the requirements of a developed rubric by Herrington (1998) which emphasized the importance of technology use, problem solving, and collaboration. The research of Bell (2010) revealed that the social skills of communication, negotiating, and collaboration with groups members can be promoted through a PBL curriculum.

My implementation of the PBL model emphasized conversations, communication, and cohesiveness among students as roles and tasks were delegated within the group. Additionally, the management of project task completion was evident and monitored closely by group members. Critical vocabulary relating to technology use and hands-on activities was shared during the process of the project. This use of critical vocabulary and sharing is evidence that the student centered PBL model supported the skills of communication and conversation. These findings are consistent with ChanLin (2008), who concluded that student centered instruction helped with the development of content understanding and development of critical thinking and problem solving skills.

Furthermore, students' vocabulary use in the area of technology use and participation in hands-on activities as they discussed a range of solutions to answering the two project's authentic driving questions are similar to the findings of Boss (2011) and Brophy et al. (2008, 2010). Their research indicated an increase in technology skill development in a PBL classroom and improved the participants motivation to problem solve and participate in hands-on activities. The results from this study also showed active student involvement with technology and hands-on activities as a benefit of using a PBL curriculum.

My students developed authentic projects that involved a variety of technology based skills, project management, and hands-on activities. These skills also appeared in the research of Davies et al. (2011), who emphasized the authentic goal of PBL. Like Davies, the use of a PBL curriculum allowed students to become involved in a variety of skills. The students' bridge models and new invention products were an application of authentic strategies, demonstrating a variety of approaches, and use of technology in the hands-on activities.

This study described the effects and experiences of how the involvement of students in small groups, with the guidance of the teacher, model real-world issues. These issues were further enhanced with the integration of technology, hands-on experiences and skills to support students' problem solving, vocabulary, and skill development with software.

Discussion of Results

Research Question 1: *How does the use of technology in PBL impact students' comprehension of geometry concepts?*

The student themes in the choice of words in the transcripts of student interviews and reflections presented in the transcribed audio and paper-based records indicated the level of comfort with the use of technology to understand geometry concepts in a PBL classroom. The audio- and paper-based records revealed that there were benefits to the use of technology to the understanding of geometry concepts within the context of group projects. My students worked through the process to project completion and communicated to the researcher openly as proof that their problem solving skills has improved. The use of a variety of technology tools provided the opportunity for my students to complete group projects and relate classroom content to real-world examples. Through the use of an assortment of technological tools, my students encountered an array of experiences into understanding geometrical concepts in a variety of ways.

Technology use in a PBL curriculum provided the opportunity for my students to engage in learning and enhancing their technology skills and the sharing of new knowledge gained from their technological use experiences. The sharing of skills and knowledge enhanced the efficiency, understanding, and motivation of my students within the group to complete the project and understanding of geometry concepts. With the aid of technology, my students were able to see and apply geometry concepts more easily as they worked through the process to complete their projects with their groups.

Furthermore, project tasks were more efficiently managed with the use of technology. As my students completed their project tasks, the results were recorded on their devices. The incorporation of technology use into a PBL curriculum not only provided for the management of the project tasks, but it allowed for the understanding of abstract ideas. Groups that encountered difficulties with understanding geometry concepts relied on their technological devices, which provided them with concrete mathematical models.

From my perspective, my students verbally exchanged and shared content knowledge gained through their use of technology as they completed project tasks. My students' initial reaction to PBL, with its emphasis on technology use, was an unfamiliar idea to many. However, the use of technology to complete projects to gain a clearer and more concrete understanding of mathematical concepts provided my students with a different way to learn mathematics. Mathematical concepts can become abstract ideas that may not be readily understood in the beginning stages. Through a group collaboration process with the incorporation of technology, my students exchanged ideas and critiqued each other. The memorization of facts and concepts might have been easily forgotten if not understood clearly, but technological tools provided the necessary resources to search for these facts. The opportunity for my students to work closely with each other through the use of technological tools and discussions helped them to discover new ideas and concepts that reinforced mathematical concepts more readily and succinctly. PBL was a new concept to many of these students, yet my students adjusted comfortably as the process of their PBL projects evolved.

The paired t-test table evaluated whether there is significant difference between two sets of conditions, nonPBL and PBL. The difference between test scores for students who experienced PBL to a students who did not experience PBL was statistically significant. There was a significant difference in the invention scores for students' post-test with no PBL (M=10.53, SD=3.83) and post-test with PBL (M=18.56, SD=8.50) conditions; $t(29) = 5.505$, $p = 0.000$. There was also a significant difference in the building a bridge scores for students' post-test with no PBL (M=11.90, SD=5.39) and post-test with PBL (M=23.20, SD=7.25) conditions; $t(29) = 7.332$, $p = 0.000$. Specifically, these results suggest that when PBL is implemented, test scores increase. However, the increase in test scores may have been tied to a maturation threat where students would have learned the material without the intervention of PBL. Through a maturation threat, the growth in understanding occurs as part of growing up is measured, and an increase or decrease in test score is not due to the implementation of PBL. Another factor that may have affected the test results can be tied a testing threat where students were already aware of what they were going to be administered or taught due to prior pre-testing information. This factor may have affected the outcome of students' post-test results.

Research Question 2: ***How does hands-on experience in PBL when practiced by students show an impact on students' comprehension of mathematical concepts?***

My students' interviews and reflections indicated terms that revealed their hands-on activity experiences in a PBL curriculum. In these findings, cooperative learning, object manipulation and perceptions emerged as the main factors that contributed to their hands-on activity experience. Group members were motivated to contribute ideas and participated in the activities when they felt that their ideas were important and understood. My students contributed their ideas and worked cooperatively with each other to fulfill the requirements of the hands-on activities. The involvement of physical movement and manipulation of objects encouraged all group members to become more active in their learning to understand the mathematical concepts underlying the activities. Group members felt more connected to what they were learning as they touched and moved objects around. Some group members shared ideas of how objects needed to be moved and placed in a certain way. When one group member disagreed with a decision, they offered an explanation for their disagreement. This created a sharing of ideas and development of critical thinking. The ability to work with their hands to build models of real-world objects helped bridge a more concrete understanding of mathematical concepts.

One benefit of PBL is the ability to incorporate hands-on activities into the learning process. The hands-on activities provided my students with a more concrete way to view a situation or problem than a textbook problem. When one student encountered an obstacle in understanding a mathematics concept, another group member stepped in and explained the concept through the use of models and manipulatives. Students' projects involved the understanding of geometrical figures and mathematical concepts. The hands-on activities provided my students with concrete examples of the concepts.

Learning mathematical concepts through a PBL approach with an emphasis on hands-on activities was a much different way of learning for many of my students. It was also a different way of teaching for me also. The use of models and manipulatives provided them with an effective way to understand a concept. However, the additional element of group discussions was an added feature which many of my students were not used to. Although mathematical concepts became less abstract with concrete objects, the exchange of ideas contributed to the successful understanding of the project. When my students did not understand a concept being used in the project, the use of models along with the exchange of ideas were observed.

From my perspective, my students were much more involved in a PBL curriculum as compared to a classroom that is taught in the traditional sense. My students were actively involved in the learning strategy. Students were thinking more critically on what they were working on than before. The ability to model a concept or move objects helped them to see abstract ideas more clearly. As my students worked closely with their group members, there were disagreements amongst group members. However, these helped to enhance the creation of a new meaning to provoke thoughtful discussions and ideas. The use of manipulatives allowed my students to see concepts three dimensionally that triggers curiosity among the students. The ability for my students to touch and work with objects allowed them to explore the characteristics of the object which may lead to the diverse interest and discovery of other possibilities of the concept being investigated.

The impact of my students' involvement in hands-on activities to the comprehension and mathematical concepts is supported by the results of a t-test results that showed that there was a significant difference in the scores for students' invention project post-test with no PBL (M=10.53, SD=3.83) and post-test with PBL (M=18.56, SD=8.50) conditions; $t(29) = 5.505$, $p = 0.000$. There was also a significant difference in the building a bridge scores for students' post-test with no PBL (M=11.90, SD=5.39) and post-test with PBL (M=23.20, SD=7.25) conditions; $t(29) = 7.332$, $p = 0.000$. My students' score in a PBL classroom were higher than a class that did not incorporate PBL. Hands-on activities were heavily incorporated into PBL activities in this study.

Research Question 3: ***How does the experience of group collaborations and discussions in PBL when applied as a problem solving strategy impact students' comprehension of mathematical concepts?***

Students' artifacts that were collected from their project-based learning curriculum projects represented the full range of the components of each project. Because the groups and teams had to be formed in a PBL curriculum, the necessity to communicate with group members to complete project tasks, task-based lessons, and the inclusion of real-world skills in final artifacts were evident.

Groups were required to create an authentic product that addressed creating a bridge model and new invention products. Groups collaborated to develop projects answering the needs of people. Group members translated the needs of people into blueprint drawings and storyboards with the use of technology and specific hands-on scaffolding activities in the planning stages to the final presentation.

The groups were also required to include number scales, angle and dimensional measurements into their blueprint drawings along with the use of logical statements into their new invention product advertisement. This required technological tools to retrieve the required information for their blueprint drawings and the new invention product advertisement. This also required the use of mathematical tools (protractors, rulers, and calculators) to measure angles and dimensions. The agreement on the accuracy of the information, type of technological tools to use, and blueprint and advertisement designs are based on decisions and collaborative discussions with each group.

The variety of blueprints and advertisement designs were influenced by the needs each group identified for people who utilize bridges and benefit from new invention products. The strongest and most enticing designs and advertisement were in groups that showed a clear communication, explanation of mathematical concepts included, and leadership roles. Meaningful and effective communication in groups addressed the needs of the project, the mathematical concepts involved in their designs and advertisement, organized roles, and requirements efficiently. Working as teams allowed group members to develop tasks, learn unclear mathematical concepts, and leadership roles to accomplish the goals of their project more successfully. The supportive group environment enabled my students to share and learn a range of mathematical and communication skills related to their projects. My students elaborated on the skills learned with the use of technology and hands-on scaffolding activities during their final presentation.

The authentic rubric was a tool used by the teacher to assess the success of each group's authentic project. A section of the rubric assesses students' problem solving process during the duration of the project from basic, proficient, and distinguished. The authentic questions such as "How do we use logical mathematical statements to advertise a new invention product?" and "How do Engineers use triangles to construct strong, stable, and safe structures?" stimulated students curiosity to come up with different solutions. The range of solutions that were found required groups to learn the uses of different technology tools, understand and apply mathematical concepts. Groups developed and designed bridge models and advertisements that addressed the authentic driving question of the projects that had specific angle, height, width and length measurements, and logical statement requirements. The success of the group's ability to problem solve is attributed to the sharing of ideas and decisions of how the bridge model and advertisement was to be designed.

From my perspective, my students' willingness to participate and work together contributed to the success of the group's ability to problem solve more effectively and objectively. When problems, issues, or concepts came up, group members worked together to solve the problem or clear up misunderstandings. When a member was absent or unable to complete their part of the project's requirements, other members were willing to step in and work through the process. Decisions of how certain components of their projects were to be designed or created was dependent on meaningful discussions within the groups. These ongoing discussions and collaborations within groups supported the problem solving process. Disagreements within group members on certain aspects of how their project should be designed helped to build new understandings, ideas, and fostered better problem solving skills.

Research Question 4: ***What is perceived by students as the most impacting factor of PBL in learning mathematical concepts?***

My student interviews, reflections and use of vocabulary words indicated their preferred way of learning new skills and mathematical concepts in a project-based learning curriculum. A wide range of preferences were expressed by my students as factors that contributed to the completion of their projects and to learning mathematical concepts.

Technological devices and software applications were heavily used and perceived as impactful by my students. These devices included their personal smart phones, classroom and personal computers, personal iPad, digital cameras and Microsoft applications. My students have stated the usefulness and influence of technological devices in the process of finishing their project requirements and final presentations. The use of technological devices have aided students with their understanding of mathematical concepts. The unfamiliarity of a concept was clarified through an internet search, from the use of the computers, and personal student phones. Through an internet search, the students found samples to confirm their conceptual understanding.

Students who were involved in project-based learning used a variety of technological devices and application. The use of Microsoft applications through Google documents allowed my students to share and edit the group's project work. Digital cameras allowed them to capture pictures of their work and create videos. Although many of my students were familiar with the uses of technology devices and supported the groups' efforts with their knowledge and skills, there were students that were unfamiliar with the use of certain technology devices. Participating in project-based learning groups enabled my students to teach each other the use of these devices. The use of sophisticated complex calculating devices enabled my students to visualize abstract mathematical concepts. Furthermore, these calculators allowed them to compute complex calculations.

Hands-on activities were also factors that impacted and contributed to my students' conceptual understanding of mathematical concepts. The opportunity to touch and move objects around provided my students with concrete examples of abstract ideas. Manipulatives modeled mathematical concepts and real-world issues. With the ability to physically move around and work with their hands, my students felt more engaged and became more involved in the process of the project. Scaffolding hands-on activities required the use of mathematical tools. The use of these mathematical tools supported my students with their mathematical understanding of the concepts. Students expressed a sense of satisfaction of being able to bridge their mathematical understanding to a model and further to a real-world issue.

My students visualized underlying mathematical concepts more easily through hands-on activities. Through the construction of bridge models, students visualized the geometrical concepts that were involved. The construction of triangles and squares in bridge models allowed students to understand the physical features and characteristics of each shape. Through an active involvement to apply mathematical concepts to authentic products (new invention, product advertisements), my students developed a deeper understanding of logic. The use of logical statements in their advertisements emphasized the importance of clear statements. The active use of rulers and protractors to measure angles and lengths of objects enabled my students to appreciate the concept of angles, width, and height.

Collaboration and discussions within their groups were highlighted as an important factor to the completion of their product and final presentation. The ability of group members to communicate and to interact with each other helped to confirm the understanding of their mathematical concepts and ideas. Being able to work together promoted teamwork and allowed for the delegation of project tasks. Completing hands-on activities required the understanding of instructions and requirements of the activities. Students with limited proficiency with their academic skills could rely on their team members to explain and clarify these requirements because the underlying mathematical skills and concepts involved in their projects might not be easily understood. Through the process of collaboration with group members, these hidden concepts could be seen more readily.

Implications of the Study

PBL is a learning strategy that can be used with or without technology and hands-on activities. Providing an appropriate amount of time for groups to plan and collaborate is important. The time allocated to students helped them to conceptualize and plan the next steps more effectively. Management roles and leadership structures evolved naturally to support learning as group members came together during the process of the projects. The encouragement of group members and group learning helped students attain critical skills and design project components. Working as groups encouraged leadership and cultivated meaningful dialogue with group members.

Also important to a successful PBL experience was the management of PBL projects that incorporated technology and hands-on activities that occurred in stages such as planning processes, technology use, participation in hands-on activities, and application of concepts. The division of the project into stages helped to manage project tasks that focused on group goals more easily. It was important that I monitored and provided guidance in the early stages of students' project idea development and planning processes closely. My students often struggled with the challenges of coming up with ideas and direction of the project. Monitoring and providing guidance during the planning stages helped my students with the development of projects that enabled them to learn and complete project tasks. The close monitoring and guidance of my students' project development stage also helped to create areas for the incorporation of technology and hands-on activities.

Student leadership roles was observed to be an important factor in groups and revolved in a variety of ways as group members interacted with each other as they completed project tasks. In most instances, group leadership was influenced by group members' mathematical knowledge, and technology and hands-on skills. Leadership roles were encouraged as groups provided direction, time management, and efficiency as the group worked together. Leadership roles in the group revolved among group members as the task requirements of the project changed.

Roles were defined in groups in the early stages of the project. Students who were skilled in specific technology tools, or software, or with their hands were often very willing to share their expertise with other students. This provided an opportunity for these expert students to lead the group and also to model the benefits of sharing their skills. As a facilitator, I occasionally checked in with groups to see who the leader is and how the group is progressing. The emphasis of group members to take initiative in doing their work was taught and stressed.

My PBL lesson planning process was developed into projects that required my students to think beyond a customary rubric for projects involving technology use and hands-on activities. PBL projects evaluated my students' holistic understanding. This included the evaluation of their technology skills, their conceptual content understanding, communication skills, and critical thinking and problem solving skills.

In this study, some groups developed creative and innovative solutions to the project's main question without the realization for the need to build their conceptions. Most of these solutions were ideas that were beyond the requirements of the projects. The initial brainstorming session at the beginning of the projects as a class helped with the fostering of ideas. Encouraging my students to brainstorm in PBL encouraged abstract thinking, and kept them engaged and motivated with a real-world context. Connecting concepts with other disciplines further enhanced my students' view of an authentic real-world problem. The invitation of professional experts into the classroom to speak allowed my students to see the working environments of these professionals. These experiences helped to enhance my students' learning beyond the limits of the classroom.

Encouraging my students' to think outside the box enabled them to develop higher order thinking skills and further to deepen their understanding of the real-world issues involved in the project. In this study, groups developed authentic products to address an authentic question that related to a real-world situation. A variety of products and solutions were provided during their final presentation. The use of an authentic driving question guided students with the objective of their projects. Authentic questions also provided my students with a direction and goal to meet the requirements of the project.

The technological tools my students used in a PBL curriculum was considered carefully. The types of technology tools to use enabled my students to search for pertinent information, clear up conceptual misunderstandings, the development of project product, and the creation of a presentation that related to the success of the project. This included the use of computers, iPad, software applications, digital cameras, calculators, and personal phones. The imaginative and creative use of these tools helped to create innovative projects. Students were required to use technological tools, but were not limited in their creative use of technology.

The planning stages of PBL took into consideration of my students' technical and leadership skills. I was aware of the fact that some students in groups may not communicate openly and the sharing of their knowledge may be minimal. Allowing students who are comfortable and willing to work with each other enabled an easy working environment. The coincidental grouping of students who were familiar and friendly with each other helped to promote better communication and sharing of learned skills and ideas.

Implications for Mathematics Teachers

For years, I have taught geometry in a very traditional way of lecturing, note-taking, and strictly assigning textbook problems. Students seem to be very passive in their learning and struggle to understand complex and abstract mathematical concepts. After trying the new teaching method of project-based learning in my classroom, I could tell the difference in students learning and understanding of the concepts and have decided to teach through this new approach. With PBL, students were more heavily engaged and active in their learning. This can be seen in my students' involvement in PBL.

Prior to the implementation of this study, I piloted an entire year of PBL instructions with my students. During that time, I adjusted for problems that occurred in anticipation of a second trial of PBL. The beginning stages of implementing a new PBL project for my students took an enormous of time. As a novice teacher who was new to a PBL curriculum, a tremendous amount of time was spent at the beginning stages to familiarize myself on how to implement a successful PBL curriculum. Learning to adjust to the demands of time that was required to develop a project was difficult. Managing the amount of time devoted to develop scaffolding activities was another obstacle. Through the process of implementing PBL in the classroom, I have learned that time management is an important factor. The ability to create a lesson that is engaging and covers the requirements of the mathematics curriculum was quite challenging. A considerable amount of time was also devoted to project planning. I understood that the amount of time that was put into the project planning phase at the beginning, impacts the process of the project and learning of the students. To adjust and decrease the amount of time that was required, I asked some of my colleagues for resources and lesson plans that I may use for my project planning. This helped to reduce the amount of time that was needed in the project planning phase.

Teachers who plan to incorporate PBL into their classroom instruction should devote a large amount of time in providing guidance and monitoring in the beginning stages of students' project work. Group dynamics is an important factor to consider when forming groups. The multiple personalities and work styles affect the group's ability to complete project tasks and to meet deadlines. Leadership roles and division of project tasks should be assigned to the groups at the beginning of project work. Time should also be incorporated into the project planning process in sharing ideas with other teachers. This process will help to generate more ideas on what may or may not work when implementing PBL. Reflecting on what was successful and what faltered during the final stages of students' projects helps to improve the process of PBL.

Group members had a wide variety of mathematical knowledge. This included their mathematical backgrounds, experiences, and understandings. The wide variety of my students' mathematical knowledge influenced the dynamics of the project's, leadership and project completion efficiency. The use of pre- and, post- examinations were used to assess my students' knowledge prior to the start and at the end of a project. This allowed for the formation of groups to be more balanced.

The inclusion of other subjects into a PBL mathematics curriculum enabled my students to relate mathematical concepts to real-world situations more easily. Through this process some of my students were able to connect mathematical concepts with real-world issues that involved other subjects. Incorporating other subjects helped my student to appreciate how mathematical concepts are applied.

Recommendations for Future Research

This study incorporated a project-based learning model that emphasized students' experience in technology use and participation in hands-on activities and group work. The study occurred at an urban high school classroom in the state of Hawaiʻi. Other possible options to conduct this study may involve larger, or smaller, specialized (English language learners, Grade level based) groups. The population size of the participants in the study helped to generate a more holistic view of student's experience in a project-based learning curriculum then a study with a smaller population. The study may also be extended for a longer or shorter period of time to examine the effects on students' learning under different time constraints and circumstances.

This study was conducted with a high school geometry class and may also be tried with different level mathematical courses (Calculus, Algebra, Trigonometry) to examine students' level of mathematical content comprehension. The success of a project-based learning lesson using technology tools and hands-on activities depends on the components of collaboration, authentic learning, leadership roles, skill development, and problem solving skills.
These components could be used and integrated with other core subject courses focusing on how students meet the requirements of an interdisciplinary project.

The students in this study were randomly assigned to groups. An approach to the use of PBL is to have groups balanced with an equal number of different academic level students. The communication and leadership roles of the groups may be different, but could provide a deeper understanding of how to implement PBL more effectively. Students in the study groups have different mathematical skill levels and processes of how they design and conceptualize ideas. The scope and requirements of the projects can be adjusted to include more activities and skill development activities.

In reference to the project goals, groups could be provided with different authentic driving questions. This allows for a wider range of different results within the groups. The different driving questions that were provided to the groups allowed students to view the same real-world issues through different angles. To enhance the authenticity of a real-world issue, professionals in the field could be invited as speakers to address students' questions and curiosity.

The study included a limited amount of responses from interviews and reflections. The data gathered represented a small portion on the impact of how effective PBL is in the classroom. Increasing the data size could add more validity and reliability to this study. Other data collection methods such as student surveys, teacher feedback forms, and administrator interview sessions could be incorporated into the study. The responses from these components helped to improve the learning process of students who are involved in the PBL curriculum.

Based on students' experiences in this PBL study, it is crucial that teachers encourage communication that focuses on skill development, project ideas, management of tasks, and a supportive working group environment. The proper authentic assessment of PBL projects is a crucial element to consider. The teacher assessment of the projects influences the goals of the PBL curriculum and also the use of technology tools and hands-on activities incorporated helped students to learn effective problem solving skills and understanding of math concepts.

Conclusion

In this study, the focus was on the students' project experiences, use of word and test scores that related to the components of the project that contributed to the successful completion of the study. There was a common use of words that related to groups working together in all collected student reflections, and interviews. These words highlighted my students' process in the delegation of project tasks and completion of the project requirements. My students' choice of words indicated the collaborative approach undertaken to complete the individual tasks and activities of the projects. The words used allowed me, the PBL teacher, to understand how students communicate in a project-based learning curriculum. The words most commonly used were displayed from the learning process in the projects.

Another factor that contributed to the success of the projects was the delegation of tasks and participation in technology, and hands-on activities. Leadership roles helped with the management of project tasks and the involvement of group members in the project. Roles were designated based upon group members' experiences and the requirements of the project. Some group members were dependent on the leadership of other members while some members volunteered to take on the roles. The leadership roles helped groups with the negotiations and sharing of tasks. This role contributed to the management of group members and to the completion of technology and hands-on specific skills.

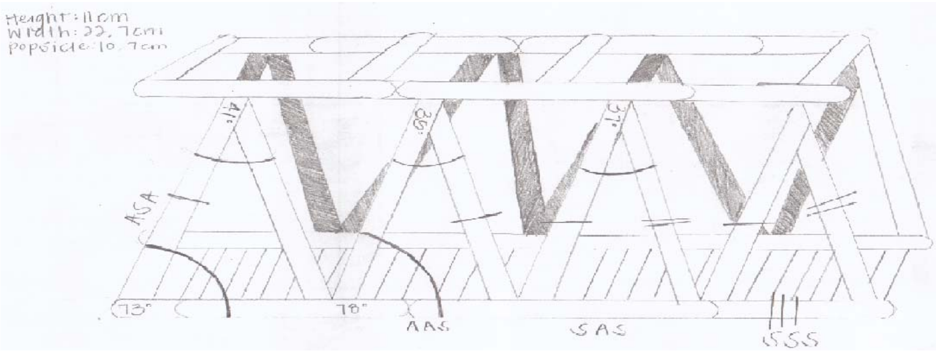
A theme of this study was to determine the impact of how technology use and participation in hands-on activities influence the learning of geometry concepts. The first task assigned to the groups was to learn and understand the requirements of the project. Project tasks were then designated according to the group members' experiences and area of strength. Group members were also paired off to complete specific project tasks. Dependent on the project requirements, some group members were designated to become experts in a particular task. These processes guided the planning, in-depth study, and development of the projects.

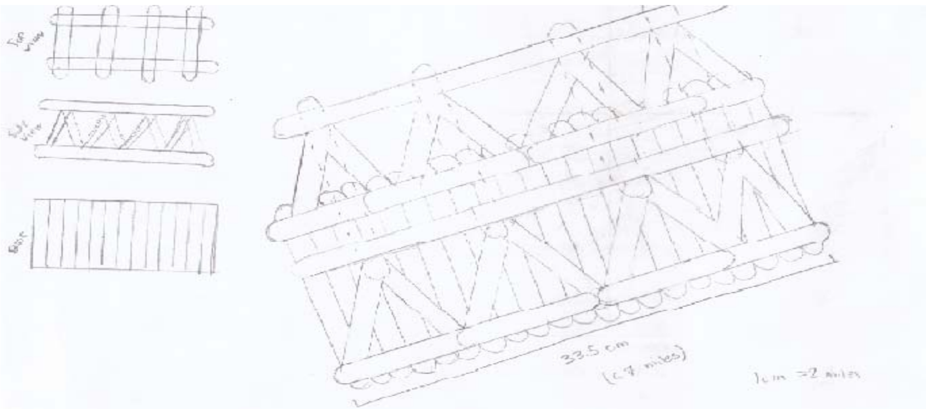
Also, this study was to provide a deeper understanding of how my students in small groups collaborated and worked together using technology, and participate in hands-on activities. As the facilitator, and teacher, I observed the communication process of my students and provided them with guidance, feedback, and support as needed. My students' main focus in their group collaboration process was to develop a solution to the project's authentic driving question through the use of technology and participation in hands-on activities. Their hands-on and technology skills, experiences and background knowledge were dependent on to meeting the goals and requirements of the project. They used an assortment of technology and mathematical tools to complete the projects. These tools represented the working resources of professionals in the real-world.

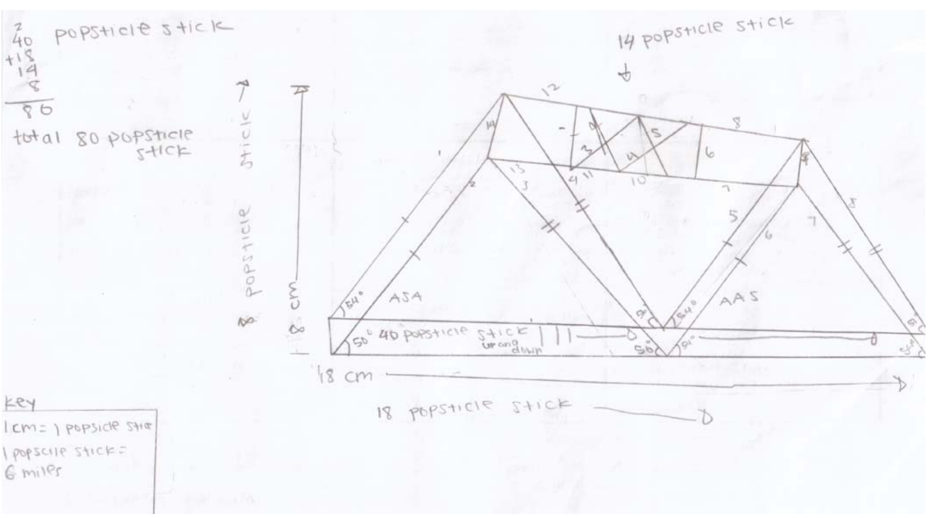
My students worked in a computer lab for the entire duration of the projects. Hands-on activity resources and manipulatives were made available at all times. This provided my students with access to computers, technology tools, and resources to conduct web searches and use of software applications. The availability of these resources replicated the working environments of professional workers in the real-world. The incorporation of the PBL curriculum to create authentic learning, involvement of technology, and hands-on activities can be implemented in a variety of classroom situations. The products produced and experiences of students in the PBL curriculum allowed me to explore the potential of incorporating the teaching model in the future.

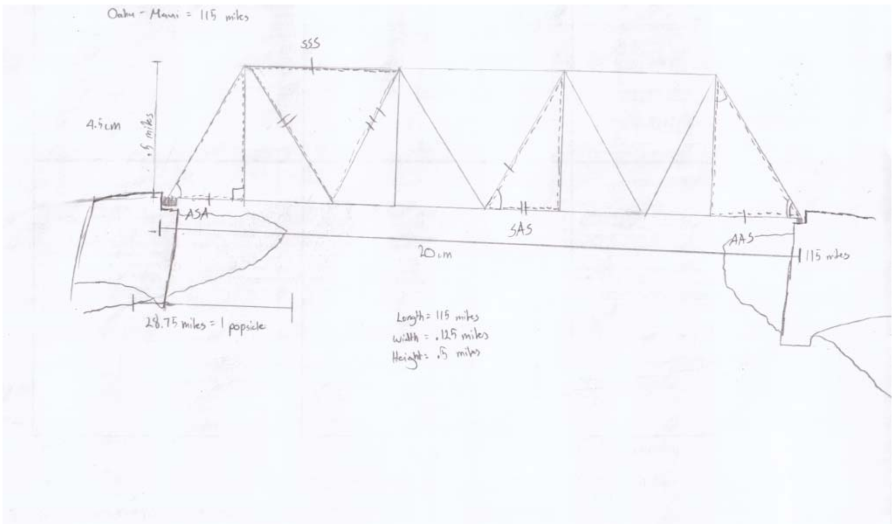
The student participants in this study used a range of technology tools and participated in a variety of hands-on activities to complete projects. Also, for me as their teacher, it was a new teaching method. In reflecting on this process, I also realized my own growth as a teacher who spent a considerable amount of time learning how to implement PBL and the time needed to do my job well. Overall, the goal of this study was to incorporate the use of technology and involvement in hands-on activities. The hope is that my students valued the use of technology, appreciated the process of collaboration, and the use and construction of models to understand complex mathematical concepts.

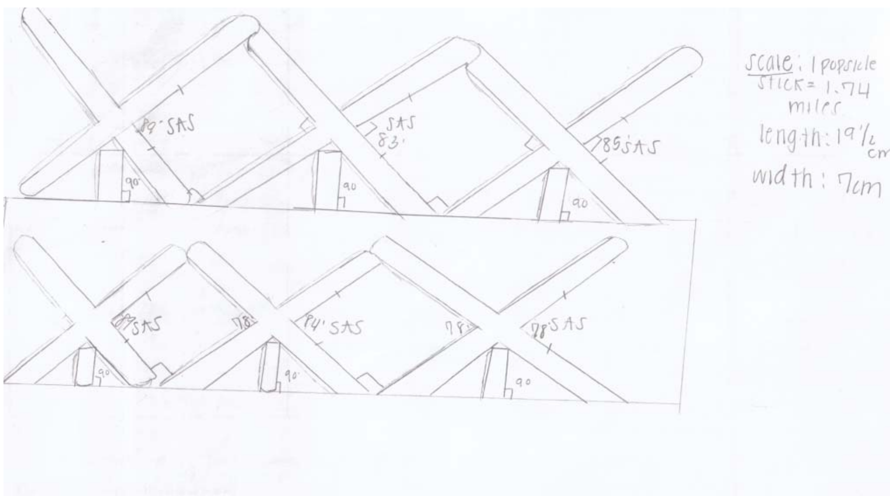
APPENDIX A
Blueprints

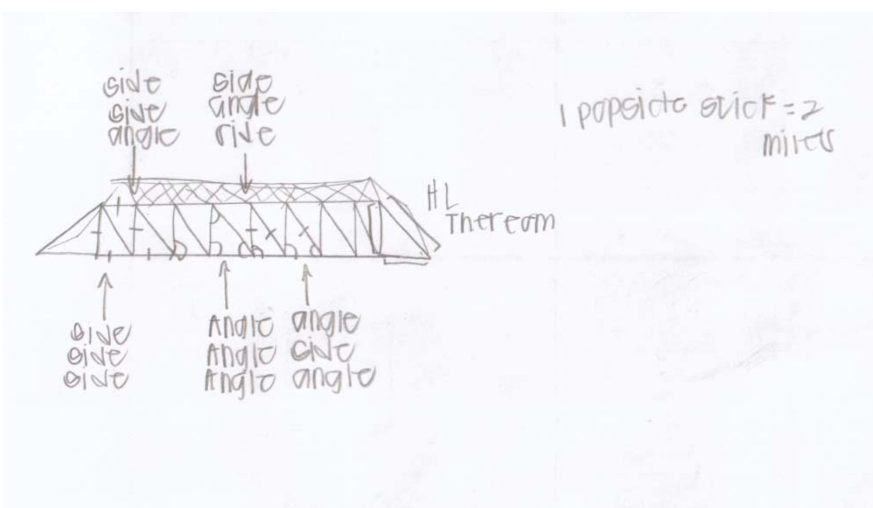




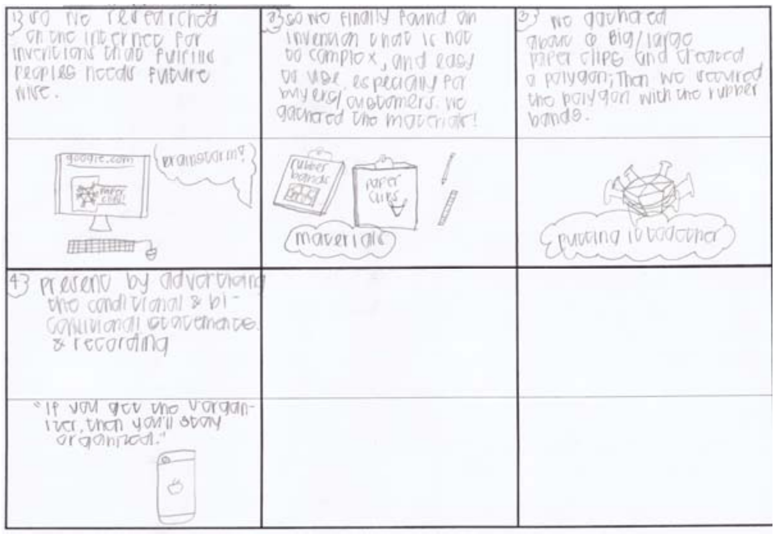


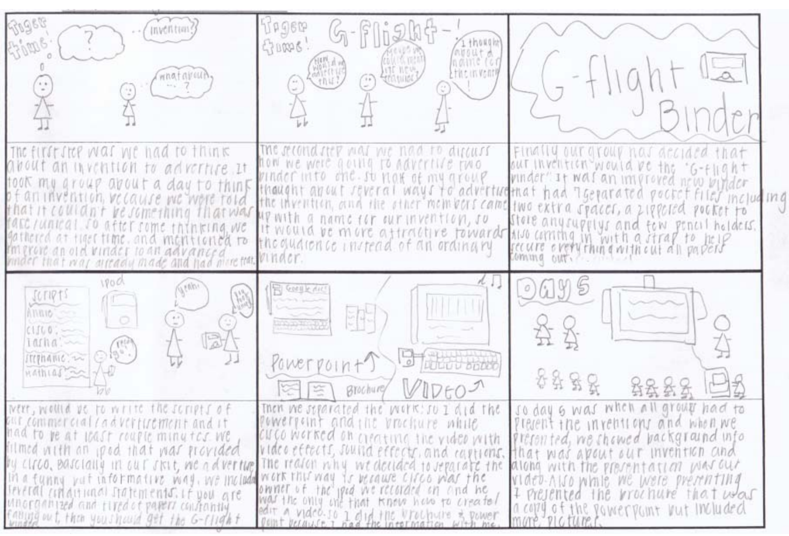

Oahu - Maui = 115 miles
SSS
4.5cm
.5 miles
ASA
SAS
AAS
20cm
115 miles
28.75 miles = 1 popsicle
Length = 115 miles
width = .125 miles
Height = .5 miles

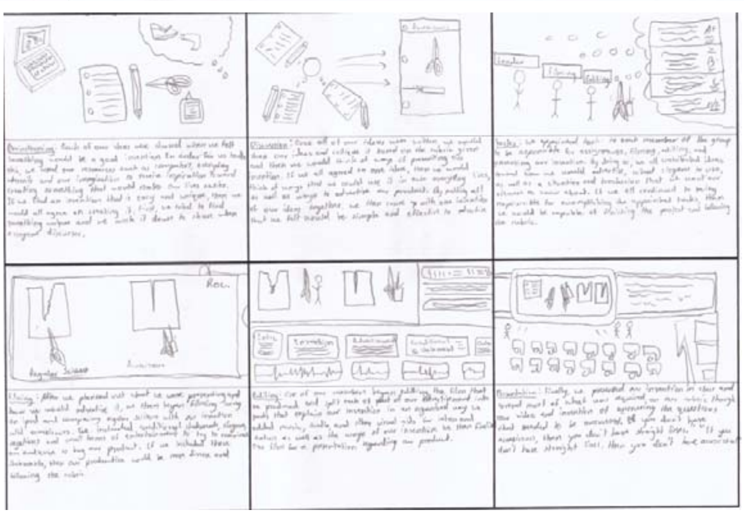

scale: 1 popsicle stick = 1.74 miles
length: 19½ cm
width: 7cm
SAS
SAS
85 SAS
SAS
SAS
SAS
90
90
90

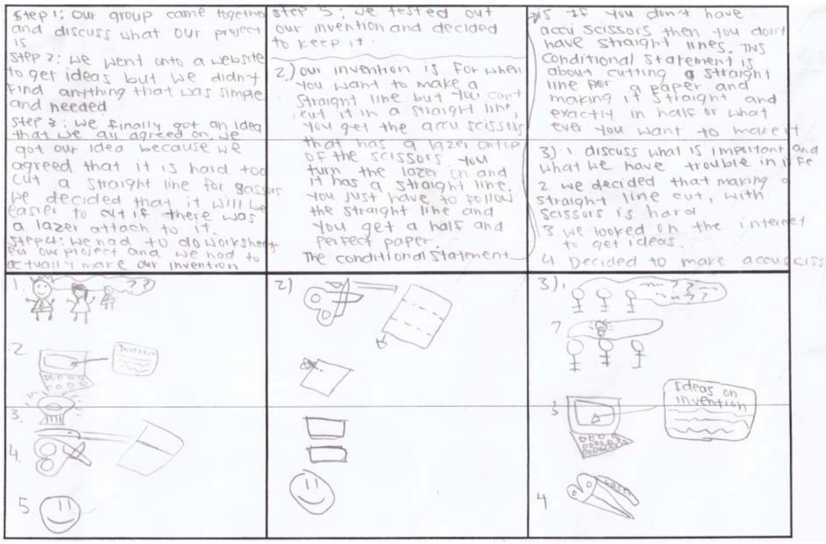

side side angle
side angle side
1 popsicle stick = 2 miles
HL Thereom
side side side
angle angle angle
angle side angle

APPENDIX B
Storyboards

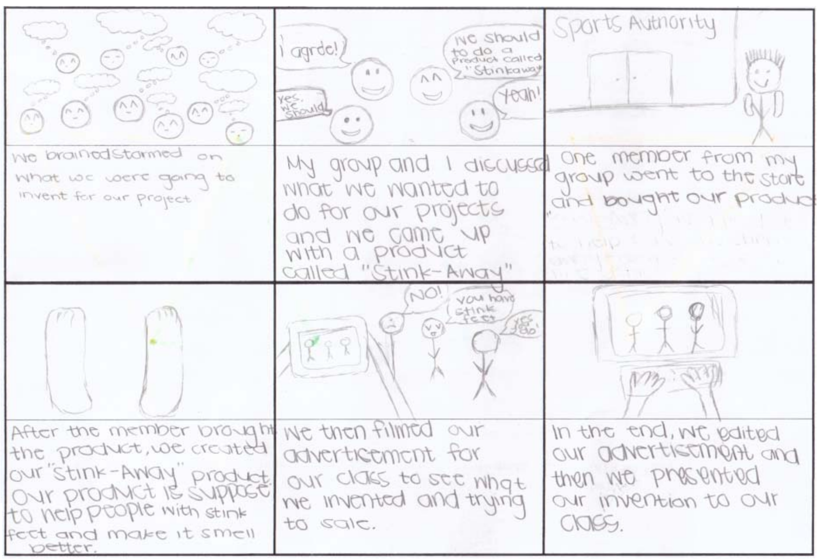




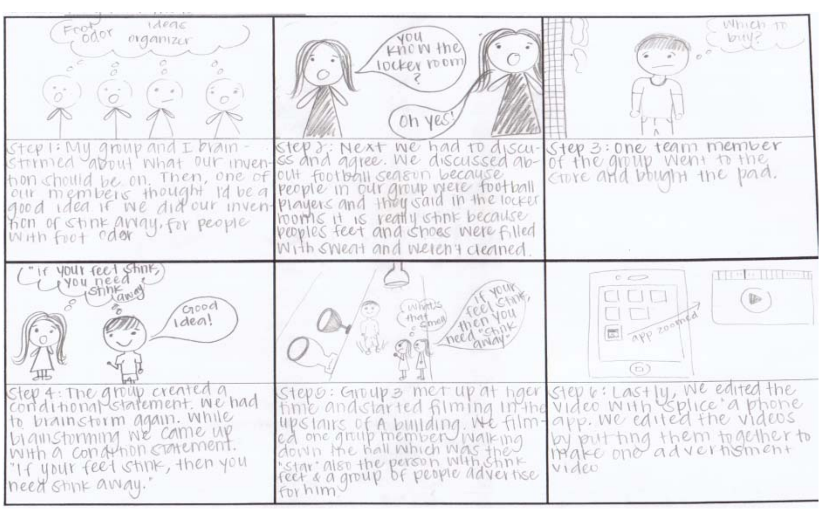




step 1: our group came together and discuss what our project is
step 2: we went onto a website to get ideas but we didn't find anything that was simple and needed
step 3: we finally got an idea that we all agreed on. we got our idea because we agreed that it is hard too cut a straight line for scissors we decided that it will be easier to cut if there was a lazer attach to it.
step 4: we had to do worksheets for our project and we had to actually make our invention
step 5: we tested out our invention and decided to keep it.
2.) our invention is for when you want to make a straight line but you can't cut it in a straight line, you get the accu scissors that has a lazer on top of the scissors you turn the lazer on and it has a straight line. you just have to follow the straight line and you get a half and perfect paper.
The conditional statement is if you don't have accu scissors then you don't have straight lines. This conditional statement is about cutting a straight line for a paper and making it straight and exactly in half or what ever you want to make it
3) 1 discuss what is important and what we have trouble in life
2 we decided that making a straight line cut, with scissors is hard
3 we looked on the internet to get ideas.
4 Decided to make accu scissors
1.
??
2
3.
4.
5
2)
3).
??
7
3
Ideas on invention
4



we brainstormed on what we were going to invent for our project
I agree!
We should to do a product called "Stinkaway"
Yes, we should
Yeah!
My group and I discussed what we wanted to do for our projects and we came up with a product called "Stink-Away"
Sports Authority
One member from my group went to the store and bought our product
After the member brought the product, we created our "Stink-Away" product. Our product is suppose to help people with stink feet and make it smell better.
NO!
you have stink feet
We then filmed our advertisement for our class to see what we invented and trying to sale.
In the end, we edited our advertisment and then we presented our invention to our class.



Foot odor
ideas
organizer
Step 1: My group and I brainstormed about what our invention should be on. Then, one of our members thought I'd be a good idea if we did our invention of stink away, for people with foot odor
you know the locker room?
Oh yes!
Step 2: Next we had to discuss and agree. We discussed about football season because people in our group were football players and they said in the locker rooms it is really stink because peoples feet and shoes were filled with sweat and weren't cleaned.
Which to buy?
Step 3: One team member of the group went to the store and bought the pad.
("If your feet stink, you need stink away")
Good idea!
Step 4: The group created a conditional statement. We had to brainstorm again. While brainstorming we came up with a condition statement. "If your feet stink, then you need stink away."
What's that smell
If your feet stink, then you need "stink away"
Step 5: Group 3 met up at tiger time and started filming in the upstairs of A building. We filmed one group member walking down the hall which was the "star" also the person with stink feet & a group of people advertise for him
app zoomed
Step 6: Lastly, We edited the video with "splice" a phone app. We edited the videos by putting them together to make one advertisment video

APPENDIX C

NEIL ABERCROMBIE
GOVERNOR

KATHRYN S. MATAYOSHI
SUPERINTENDENT

STATE OF HAWAI'I
DEPARTMENT OF EDUCATION
P.O. BOX 2360
HONOLULU, HAWAI'I 96804

OFFICE OF THE SUPERINTENDENT

July 26, 2013

Mr. William Chin

Dear Mr. Chin:

I am pleased to approve your application for the research project "Implementing Project-Based Learning in 9th Grade Geometry" (Study #201264279761), which seeks to:

- Examine what aspects of project-based learning activities affect students' understanding of geometry concepts.
- Determine what aspects of 21st-century learner skills help to enhance students' geometric understanding.

As described in your application, you will be inviting students from two ninth-grade geometry classes to participate in your research project during one quarter of School Year 2013-2014.

I understand that all 60 students enrolled in the targeted geometry classes will receive instruction on the two geometry chapters on which your research project is focused and will participate in all related coursework and assessments; however, the data produced by participating students (those whose parents have consented to their participation and who themselves have assented to participating in the research project) as a result of their participation in the following activities will be used for your research project:

- Four sub-lesson quizzes per chapter (eight sub-lessons total).
- One final exam per chapter (two final exams total).

In addition, participating students will:

- Complete a five-question reflection worksheet five times during the quarter.
- Take part in a 10-minute one-on-one interview once during the quarter.
- Be the subject of five-minute observations that you will conduct three times during the quarter.

Please be aware of the following:

- All interviews must take place during non-instructional hours.
- In accordance with the Family Educational Rights and Privacy Act (FERPA), the only student data that you are authorized to use for your research project are those for which you have obtained consent to use from participating students' parents/guardians. Please note that, although you may have access to additional

AN AFFIRMATIVE ACTION AND EQUAL OPPORTUNITY EMPLOYER student and non-public HIDOE data in your role as a HIDOE teacher, you may not use these data for your research project without the prior written consent of the students' parents/guardians and/or an approved HIDOE data request.

Should you wish to use student or non-public HIDOE data beyond those described above, you must submit a research application modification request to the Data Governance Office, along with a revised parent/guardian consent form or a completed data request form, as appropriate. You may only use these additional data for your research project after:

1. I have approved your modification request and
2. You have obtained parent/guardian consent using the revised form and/or your data request has been approved by the appropriate data steward.

- You are required to conduct your research project in accordance with both the conditions of approval described in this letter and the document "Affirmation and Acknowledgement of the Processes, Procedures, and Conditions for Conducting Research in the Hawaii State Department of Education" (the "Affirmation Form for Researchers"), which you signed and submitted as part of your research application.
- You are responsible for ensuring that all individuals involved in this research project — both those affiliated with your organization and those contracted by your organization and affiliated with external entitites or vendors — adhere to all of the conditions of my approval, including those detailed in this letter and those stipulated by the Affirmation Form for Researchers.

Included for your reference below are some of the processes, procedures, and conditions for conducting research in HIDOE that are included in this form; please note, however, that this list is not exhaustive. For the full contents of the form, please refer to your signed copy, which you have attached to Tab 6 of your research application, or to the blank copy available for download from the HIDOE Research website at http://apps.hidoe.k12.hi.us/research/Pages/FormsResources.aspx.

As stipulated by the Affirmation Form for Researchers:

- Participation in the research project by HIDOE students and personnel will be strictly voluntary and contingent upon obtaining — prior to their participation in the research project:
    a. The written approval of the relevant school or office administrator(s),
    b. The written consent of all adult participants (which includes students 18 years and older),
    c. The active assent of participants who are minors, and
    d. The written consent of the guardians of all minor participants;
- Oral instructions must be provided for all participant activities related to the research project that involve minor students;
- After consenting to participate in the research project, participants (and, in the case of minor participants, their guardians on their behalf) may withdraw at any time, for any reason;
- All activities related to the research project must take place at dates, times, and locations agreed upon by the administrators of the participating schools and offices;
- Any compensation provided to HIDOE personnel for participation in the research project must be for activities completed outside of instructional and work hours;

- Copies of the research project's data collection instruments (e.g., surveys, interview schedules) must be presented to the administrators of the participating schools and offices for review prior to the implementation of the research project;

- If the research project will involve participants who are minor students, a copy of the relevant data collection instrument(s) must, upon request, be made available to the students' guardians for review in the office of the participating school prior to the implementation of the research project;

- All data collected during the course of implementing the research project or made available to you by HIDOE for the research project (including, but not limited to, completed surveys, interview responses, video recordings, audio recordings, and HIDOE data sets) must be destroyed when the final report on the research project is complete or at the end of your research project's one-year approval period (which ends 12 months from the date of this letter), whichever date is sooner;

- At least two (2) weeks prior to printing, publishing or otherwise publicly releasing the final report on the research project, electronic copies of a final draft must be submitted to:

    a. The administrators of the participating schools and offices for their review, and

    b. If the research project involves either participants who are HIDOE students or personnel or the collection and/or receipt of personally identifiable HIDOE student or personnel data, to the Data Governance Office to be screened for the inclusion of personally identifiable HIDOE student and personnel data; and

- Upon request, electronic copies of the final report on the research project must be shared with:

    a. Participants in the research project,

    b. The complex area superintendents of the participating schools, and

    c. The assistant superintendents/directors of the participating HIDOE offices.

Should you have any questions about the above, please contact Jennifer Higaki, HIDOE Data Governance Office, at DOEresearch@notes.k12.hi.us or (808) 440-2854.

Best wishes for a successful research project. We look forward to receiving your findings and recommendations.

Very truly yours,

for Kathryn S. Matayoshi
Superintendent

APPENDIX D

NEIL ABERCROMBIE
GOVERNOR

KATHRYN S. MATAYOSHI
SUPERINTENDENT

STATE OF HAWAII
DEPARTMENT OF EDUCATION

January 29, 2013

To: Kathryn Matayoshi, Superintendent

From: Ron Okamura, Principal

Subject: Letter of Support for William Chin's Research Project

I am writing in support of Math Teacher William Chin's research project assessing the effectiveness of project-based learning in Geometry. His study will address pedagogy and assessment of the geometry content and performance standards.

This research is important to our school and the state as we move forward in developing new strategies for our students working to meet the mathematics requirement for a high school diploma. This study also supports our school goal of proficiency for all students in math courses that are required for college readiness. Many of our students are learning English as a new language and opportunities for them to demonstrate knowledge through real-world projects is an approach we want to study in more depth. William's project will strengthen our knowledge about project-based learning and its application to geometry instruction.

We encourage teachers to engage in research-based practices that support increased student achievement. Through his research William will engage in an analysis of this pedagogy and develop applications for our students. I believe that his findings will provide us with important data that will enable us to improve our students' competency in mathematics.

I fully endorse William's proposed research project.

APPENDIX E

University of Hawai'i
Parental/Guardian's Consent for Child to Participate in Research Project:
Project-Based learning in Geometry

My name is William Chin. I am your child's math teacher and a graduate student at the University of Hawai'i at Manoa (UH). A requirement for earning my Doctorate's degree is to do a research project. The purpose of the project is to determine what aspects does project-based learning effect geometry learning at their school.

Project Description- Activities and Time Commitment: Participation in the project will consists of completing a project journal, reflections, exams and an interview session for the duration of 4 weeks of a quarter of the school year. I will have students' complete reflections which will consist of the following questions: 1.What did you learn today? 2. How did you feel about your work today? 3.What class activity was most useful to you? 4.What class activity was least useful to you? 5.What do you need to continue to work?

Benefits and Risks: I believe there are no direct benefits to your child; however the results of the project might help me, other teachers, and researchers learn more about high school students' perspective on learning mathematics through project-based learning. I believe there is little risk on your child's participation in this research project.

Confidentiality and Privacy: During this research project, I will keep all data in a secure location. No personal identifying information will be included with the research results. Only my University of Hawaii advisor and I will have access to the data, although legally authorized agencies, including the University of Hawai'i Human Studies Program, have the right to review research records.

Voluntary Participation: Participation in this research is completely voluntary. You are free to withdraw your child from participation at any time during the duration of the project with no penalty. Participation or non-participation in the research will have no effect on your child's grades or class standing.

Questions: If you have any questions regarding this research project, you can contact me at (808) 594-0400 or ChinW25@hawaii.edu. You can also contact my advisor at the University of Hawaii, Dr. Thanh Truc T Nguyen, at (808) 956-6507 or nguyen@hawaii.edu. If you have any questions regarding your rights as a research participant, please contact the UH Committee on Human Studies at (808) 956-5007, or uhirb@hawaii.edu. Please keep the attached copy of the consent form for your reference.

Parent/Guardian: I give permission for my child to participate in the research project entitled "What Aspects Does Project-Based Learning Effect Geometry Learning" I understand that, in order to participate in this project, my child must also agree to participate. I understand that my child and/or I can change our minds about participation, at any time, by notifying the researcher on our decision to end participation in this project.

______________________________	______________________________
Student Name (Printed)	Parent/Guardian Name (Printed)
______________________________	______________________________
Date	Parent/Guardian Name (Signature)

APPENDIX F

University of Hawai'i
Assent for Child (9-12th grade) to Participate in Research Project

Researcher: William Chin

Study Title: Project-based learning in Geometry

1. WHAT IS THIS FORM?
This form is called an Assent Form. It will give you information about the study so you can make a decision about whether you want to participate or not.

2. WHAT IS THIS STUDY ABOUT?
Research is a way to learn more about people. I am doing a research study on what aspects does project-based learning effect Geometry learning because I don't know very much about whether students at your age learn mathematics better through projects or through other teaching methods.

3. WHAT WILL I BE ASKED TO DO?
If you decide that you want to be part of this study, you will be asked to complete a project journal, reflections, exams and an interview session for the duration of 4 weeks of a quarter of the school year. You will complete reflections which will consist of the following questions: 1.What did you learn today? 2. How did you feel about your work today? 3.What class activity was most useful to you? 4.What class activity was least useful to you? 5.What do you need to continue to work?

There are some things you should know about this study. Not everyone who takes part in this study will benefit. There are no direct benefits to you from being in this research study. However, I or other teachers, and researchers may learn more about high school students' feelings on learning mathematics through project-based learning.

4. PROTECTION OF INFORMATION?
Your name will not be in any report of the results of this study. No personal identifying information will be included with the research results. Only my University of Hawaii advisor and I will have access to the data, although legally authorized agencies, including the University of Hawai'i Human Studies Program, have the right to review research records.

5. PARTICIPATION?
Participating in this research is completely voluntary. You are free to withdraw from participation at any time during the duration of the project with no penalty. Participation or non-participation in the research will have no effect on your grades or class standing.

6. QUESTIONS?
If you have questions and do not understand any part of the study you can ask me. If your parents have other questions and worries, they can contact me at (808) 594-0400 or ChinW25@hawaii.edu. They can also contact my advisor at the University of Hawaii, Dr. Thanh Truc T Nguyen, at (808) 956-6507 or nguyen@hawaii.edu and the UH Committee on Human Studies at (808) 956-5007, or uhirb@hawaii.edu. Please keep the attached copy of this assent form for yourself as a reference.

If you decide you want to be in this study, please sign your name.

I, ____________________________, want to be in this research study.
(Print your name here)

_______________________________ ____________________
(Sign your name here) (Date)

APPENDIX G

UNIVERSITY of HAWAI'I®
MĀNOA

Office of Research Compliance
Human Studies Program

March 15, 2013

TO: William Chin
Principal Investigator
College of Education

FROM: Denise A. Lin-DeShetler, MPH, MA
Director

Re: CHS #21083- "Project-Based Learning in Geometry"

This letter is your record of the Human Studies Program approval of this study as exempt.

On March 15, 2013, the University of Hawai'i (UH) Human Studies Program approved this study as exempt from federal regulations pertaining to the protection of human research participants. The authority for the exemption applicable to your study is documented in the Code of Federal Regulations at 45 CFR 46.101(b) (1).

Exempt studies are subject to the ethical principles articulated in The Belmont Report, found at http://www.hawaii.edu/irb/html/manual/appendices/A/belmont.html

Exempt studies do not require regular continuing review by the Human Studies Program. However, if you propose to modify your study, you must receive approval from the Human Studies Program prior to implementing any changes. You can submit your proposed changes via email at uhirb@hawaii.edu. (The subject line should read: Exempt Study Modification.) The Human Studies Program may review the exempt status at that time and request an application for approval as non-exempt research.

In order to protect the confidentiality of research participants, we encourage you to destroy private information which can be linked to the identities of individuals as soon as it is reasonable to do so. Signed consent forms, as applicable to your study, should be maintained for at least the duration of your project.

This approval does not expire. However, please notify the Human Studies Program when your study is complete. Upon notification, we will close our files pertaining to your study.

If you have any questions relating to the protection of human research participants, please contact the Human Studies Program at 956-5007 or uhirb@hawaii.edu. We wish you success in carrying out your research project.

1960 East-West Road
Biomedical Sciences Building B104
Honolulu, Hawai'i 96822
Telephone: (808) 956-5007
Fax: (808) 956-8683

APPENDIX H
OBSERVATION CHECKLIST

Group:			
Project Name:		**Date**:	

When beginning a new task, group members …				
Behavior observed	**All members**	**Most members**	**Some members**	**Fe w members**
Agree on an agenda or plan				
Begin work promptly				
Get out project materials				
Figure things out without minimal teacher help				
Share responsibilities and/or assign roles				
Review deadlines				

When working, group members….				
Behavior observed	**All members**	**Most members**	**Some members**	**Fe w members**
Have relevant conversations				
Evaluate new information for significance				
Teach each other				
Assign overnight/weekend tasks				

Ensure that work is turned in				
Ask for help when needed				

When discussing project work, group members….				
Behavior observed	**All members**	**Most members**	**Some members**	**Fe w members**
Ask clarifying questions				
Take turns speaking				
Make decisions collaboratively				
Record decisions and plans				
Share essential information				
Review deadlines				

APPENDIX I
Interview Questions

Thank you for your time. Do you have any questions, before we begin the interview? You will be asked nine questions related to project-based learning. Feel free to give your honest answer. There are no right or wrong answers. You will not be penalized and your grades or class standing will not be affected because of your answers.

1. What went through your mind when you first learned about this project in class?

2. What were some of the things about the project that motivated you?

3. How did you go about completing the project task?

4. What types of technology tools did you use?

5. What were some of the most important things you learned while in the process of working on your project?

6. Would you have preferred to write a research paper or do this type of project?

7. What are the skills most needed in completing the project, and how do you improve these skills?

8. What are the strengths and weaknesses in your project?

9. What suggestions would you make to me to improve the project?

APPENDIX J
Authentic Rubric
Based on
(Herrington & Herrington, 1998)

Category	**1-3 (Basic)**	**4-6 (Proficient)**	**7-9 (Distinguished)**
Context	Created a project that basically ***addresses*** the issues of real-world questions. Project indicates a basic ***level of knowledge*** to the issues of the problem and on how completed tasks and skills connected to real-world situations.	Created a project which ***addressed*** the issues of real-world questions. Project indicates a ***proficient knowledge*** of the issues of the problem and on how completed tasks and skills related to real-world situations.	Created a project that ***emphasizes*** the issues of real-world questions. Project indicates a **distinguished emphasis** on the issues of the problem and on how completed tasks and skills related to real-world situations.
Problem Solving	Final project displays a ***basic level*** of problem-solving skills, higher order critical thinking, the production of original knowledge and not the duplication of knowledge, extensive student work time, depth of knowledge.	Final project displays a ***proficient level*** of problem-solving skills, higher order critical thinking, the production of original knowledge and not the duplication of knowledge, extensive student work time, depth of knowledge.	Final project displays a ***distinguished level*** of problem-solving skills, higher order critical thinking, the production of original knowledge and not the duplication of knowledge, depth of knowledge.

Task Factors	A ***basic*** response to the project's authentic question. A ***basic*** project is displayed where students answered and solved some of the components to the project's question. Most of the necessary steps to complete the project were addressed.	A ***proficient*** response to the project's authentic question. A ***proficient*** project is displayed where students answered and solved ***all*** of the components to the project's question. Most of the necessary steps to complete the project were addressed.	A ***distinguished*** response to the central authentic question. A ***distinguished*** project is displayed where students answered and solved all the components to the project's question. Most of the necessary steps to complete the project were addressed.
Level of Success	A ***basic*** level of reliable product is created to address most of the needs of the question. Final product indicates an inclusive involvement of technology and hands-on skills.	A ***proficiently*** valid and reliable product is created to address the fundamental needs of the question. Final product indicates an inclusive involvement of technology and hands-on skills.	A ***distinguished*** level of valid and reliable product is created to address the needs of the question. Final product indicates an inclusive ***distinguished*** involvement of technology and hands-on skills.

APPENDIX K

Reflection Questions

Student name:			
Project Name:		Date:	

Today I had the following <u>goals</u> for project work	1	
	2	
	3	
	4	
	5	

Today I accomplished…	1	
	2	
	3	
	4	
	5	

My next steps are…	1	
	2	
	3	
	4	
	5	

My most important concerns, problems or questions are…	1	
	2	
	3	
	4	
	5	

References

Access Group. (2013). *Math*. Retrieved from http://www.accessgroupinc.org/page/195/academymath#Mastering_Mathematics:_Needed_Components

American Association for the Advancement for Science. (2009). *Benchmarks online*. Retrieved from http://www.project2061.org/publications/bsl/online/index.php?chapter=2

Ames, C. A. (1990). Motivation: What teachers need to know. *Teachers College Record*, *90*(3), 409–421.

Artzt, A.F., Armour-Thomas, E., & Curcio, F. R. (2008). *Becoming a reflective mathematics Teacher: A Guide for observations and self-assessment (Studies in mathematical thinking and learning series).* New York: Lawrence Erlbaum Associates.

Barron, B., & Darling-Hammond, L. (2008). Teaching for meaningful learning: A review of research on inquiry-based and cooperative learning. *Powerful learning: What we know about teaching for understanding* (pp.11-70). San Francisco, CA: Josey-Bass.

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House*, *83*(2), 39–43.

Benesch, S. (1984). Improving peer response: Collaboration between teachers and students. *Journal of Teaching Writing*, *4*(1), 87–94.

BIE.com. (2012). *Project-based learning*. Retrieved from www.bie.org

Bloemart, S. (2013). *Dealing with the fear of change*. Retrieved from http://www.coetail.com/educationjourney/2012/11/01/dealing-with-the-fear-of-change/

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M. and Palincsar, A. (1991). Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning. *Educational Psychologist, 26*(3-4), 369–398.

Boaler, J. (1997). Equity, Empowerment and Different Ways of Knowing. *Mathematics Education Research Journal, 9*(3), 325–342.

Boss, K., & Krauss, J. (2008). *Reinventing Project-based learning: Your field guide to real-world projects in the digital age*. Eugene, OR: International Society for Technology in Education.

Boss, S. (2011). *Project-Based Learning: A Short History*. Retrieved from http://www.edutopia.org/project-based-learning-history

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education*, *97*(3), 369–387.

Centre for Education in Science & Technology. (2008). *Importance of technology in schools*. Retrieved from http://www.cest.org.uk/importance-of-technology-in-schools/

ChanLin, L. J. (2008). Technology integration applied to project-based learning in science. *Innovations in Education and Teaching International*, *45*, 55–65.

Chen, W. H. (2013). Teaching Geometry through Problem Based Learning and Creative Design. In C. Long & N. Mastorakis (Eds.), *Proceedings of the 2013 International Conference on Education and Educational Technologies* (pp. 235–238). Rhodes Island, GR: NOVA.

Chetty, L. C. (2012). *The importance of technology in the classroom*. Retrieved from http://www.thoughtleader.co.za/leeroychetty/2013/04/02/the-importance-of-technology-for-education/

Civic Enterprises. (2012). *Building a grad Nation*. Retrieved from http://new.every1graduates.org/wp-content/uploads/2012/03/BuildingAGradNation2012-WebVersion-Final-031712.pdf

Clements, D. (2003). *Teaching and learning Geometry*. Retrieved from https://moodle.education.wisc.edu/pluginfile.php/8773/mod_resource/content/0/Van_Hiele_model_readings/Clements_2003.pdf

Collins, E.N., Perkins, G., Wellman, N., & Wellman, W. (2011). Using technology to impact student motivation. In M. Koehler & P. Mishra (Eds.), *Proceedings for Information Technology & Teacher Education International Conference 2011* (pp. 4451–4453). Chesapeake, VA: Association for the Advancement of Computing in Education.

Crook, C., Harrison, C., Farrington-Flint, L., Tomás, C., & Underwood, J. (2010). *The impact of Technology: Value-added classroom practice*. Coventry: Becta.

Curtis, D. (2013). *Laptops on expedition: Embracing expeditionary learning*. Retrieved from http://www.edutopia.org/stw-maine-project-based-learning-king-expeditionary-learning

Daniels, H., & Bizar, M. (1998). *Methods that matter. Six structures for best classroom practice*. Retrieved from http://www.csun.edu/~krowlands/Content/Academic_Resources/Best_Practices/Beating%20the%20Odds/Daniels-Methods%20That%20Matter.pdf

Davies, J., de Graaff, E., & Kolmos, A. (2011). *PBL across the disciplines: Research into best practice*. Aalborg: Aalborg University Press.

Edutopia Staff. (2011). *PBL research summary: Studies validate project-based learning*. Retrieved from http://www.edutopia.org/project-based-learning-research

Edutopia Staff. (2012). *Why Integrate Technology into the Curriculum?: The Reasons Are Many*. Retrieved from http://www.edutopia.org/technology-integration-introduction

Edutopia Staff. (2012a). *PBL research summary: Studies validate project-based learning*. Retrieved from http://www.edutopia.org/project-based-learning-research

Edutopia Staff. (2012b). *Research-supported PBL practices*. Retrieved from http://www.edutopia.org/stw-project-based-learning-best-practices-new-tech-research

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education*, *42*(3), 255–284.

Flattau, P., & Bracken, J. (2007). *The national defense act of 1958: Selected outcomes*. Retrieved from https://www.ida.org/upload/stpi/pdfs/ida-d-3306.pdf

Froyd, J., & Simpson, N. (2008). *Student-centered learning addressing faculty questions about student-centered learning*. Retrieved from http://ccliconference.org/files/2010/03/Froyd_Stu-CenteredLearning.pdf

Geist, E. A., & King, M. (2008). Different, Not Better: Gender Differences in Mathematics Learning and Achievement. *Journal of Instructional Psychology*, *35*(1), 43–52.

George Lucas Educational Foundation. (2004). *Project Based Learning Research*. Retrieved from http://www.glef.org/PBL/reasearch.html

Globalschoolnet. (2003). *Assessment of project-based learning*. Retrieved from http://www.gsn.org/web/pbl/plan/assess.htm

Goldenberg, E. (2000). *Thinking (and talking) about technology in math classrooms.* Retrieved from http://www2.edc.org/mcc/pdf/iss_tech.pdf

Hakkarainen, P. (2009). Designing and implementing a PBL course on educational digital video production: Lessons learned from a design-based research. *Educational Technology Research & Development*, *57*(2), 211–228.

Haylock, D., & Cockburn, A. D. (2008). *Understanding mathematics for young children: A guide for foundation stage and lower primary teachers*. Thousand Oaks, CA: Sage.

Heafner, T. (2004). Using technology to motivate students to learn social studies. *Contemporary Issues in Technology and Teacher Education*, *4*(1), 42-53.

Hernandez-Ramos, P., & La Paz, S. D. (2009). Learning history in middle school by designing multimedia in a project-based learning experience. *Journal of Research on Technology in Education*, *42*(2),151-173.

Herrington, J, & Herrington, A. (1998). Authentic assessment and multimedia: How university students respond to a model of authentic assessment. *Higher Education Research and Development, 17*(3), 305–322.

Hoffman, B., & Nadelson, L. (2010). Motivational engagement and video gaming: A mixed methods study. *Educational Technology Research and Development*, *58*(3), 245–270.

Hosler, A. (2013). *What you should know about project-based learning*. Retrieved from http://www.educationworld.com/a_curr/project-based-learning-benefits-best-practices.shtml

Iadiapaolo, D. (2011). *How to implement project-based learning to engage students*. Retrieved from http://www.lessonplanet.com/article/math/how-to- implement-project-based-learning-to-engage-students

Intel Corporation. (2007). *Designing effective projects*: *Characteristics of projects benefits of project-based learning.* Retrieved from http://download.intel.com/education/Common/ro/Resources/DEP/projectdesign/DEP pbl_research.pdf

Jones, K., & Fujita, T. (2001). Developing a new pedagogy for geometry. *Proceedings of the British Society for Research into Learning Mathematics*, *21*(3), 90–95.

Judson, E. (2010). Improving technology literacy: Does it open doors to traditional content? *Educational Technology Research and Development 58*(3)*,* 271–284.

Ko, S.Y. (2004). *Project-based learning in a Hong Kong secondary school: Perceptions of teachers and students*. Retrieved from http://hub.hku.hk/bitstream/10722/32169/1/FullText.pdf

Krulock, L., & Landini, E. H. (2011). *Why are 21st century skills important?* Retrieved from http://theintelligencer.net/page/content.detail/id/552994/Why -Are--21st-Century--Skills-Important-.html?nav=505

Kyndt, E., Dochy, F., Struyven, K., & Cascallar, E. (2010). The direct and indirect effect of motivation for learning on students' approaches to learning through the perceptions of workload and task complexity. *Higher Education Research and Development, 30*(2), 135–150.

Land, S. M., & Greene, B. A. (2000). Project-based learning with the World Wide Web: a study of resource integration. *Educational Technology Research and Development, 48,* 45–66.

Lester, S. (2011). *Special technology report: Lessons learned from one-to-one*. Retrieved from http://www.districtadministration.com/article/special-technology-report- lessons-learned-one-one

Liegel, K. (2004). *Project-based learning and the future of project management* Retrieved from http://www.makeithappen.ws/uploads/PBL_Future_of_Project_Management_ KLiegel_2004.pdf

Liu, M., Horton, L., Olmanson, J., & Toprac, P. (2011). A study of learning and motivation in a new media environment for middle school science. *Educational Technology Research and Development*, *59*, 249–265.

Liu, W. C., Divaharan, S., Peer, J., Quek, C. L., Wong, F. L. A., & Williams, M.D. (2004, 28 November – 2 December). *Project-Based Learning and Students' Motivation-The Singapore Context.* Paper presented at the Proceedings of the Australian Association for Research in Education Conference, Melbourne, AU.

Markham, T. (2011). Project-Based learning. *Teacher Librarian, 39*(2), 38–42.

Mayer, R. E., & Alexander, P. A. (Eds.). (2011). *Handbook of research on learning and instruction*. New York, NY: Routledge.

McCusker, S. (2013). *Navigating the first year in a 1:1 classroom*. Retrieved from http://gowhereyougrow.wordpress.com/

Mergendoller, J.R., Markham, T., & Ravitz, J. (2006). Pervasive management of project based learning: Teachers as guides and facilitators. In C.M. Evertson & C.S. Weinstein (Eds.), *Handbook of classroom management: Research, practice, and con-temporary issues,* Mahwah, NJ: Lawrence Erlbaum, Inc.

Merriam-Webster's collegiate dictionary. (2013). Springfield, MA: Merriam Webster.

Moursund, D. (1999). *Project based learning using information technology*. Eugene, Oregon: International Society for Technology in Education.

Nadelson, L. (2000). Discourse: Integrated problem solving and project-based learning in high school mathematics. *Northwest Teacher, 1*, 20.

Nguyen, K. (2011). *How to establish rapport in the classroom*. Retrieved from http://www.teachingenglish.org.uk/blogs/khanh-nguyen/how-establish-rapport-classroom

Noboro, M. (2012). *What makes project-based learning a success?* Retrieved from http://www.edutopia.org/stw-project-based-learning-best-practices-new-tech-high-school#more

Penuel, B., Korbak, C., Yarnall, L., & Pacpaco, R. (2001). *Silicon Valley challenge 2000: Year 5 multimedia project report*. Menlo Park, CA: SRI International.

Pieratt, J.R. (2011). *Teacher-student relationships in project-based learning: A case of high tech middle north county*. Retrieved from http://scholarship.claremont.edu/cgi/viewcontent.cgi?article=1012&context=cgu_etd

Polya, G. (2008). *How to solve it: A new aspect of mathematical method*. Princeton, New Jersey: Princeton University Press.

Railsback, J. (2002). *Project-based instruction: Creating excitement for learning*. Portland, Oregon: Northwest regional educational laboratory.

Ravitz, J., & Blazevski, J. (2010). *Assessing the impact of online technologies on PBL use in US high schools*. Retrieved from http://bie.org/images/uploads/general/8e4c7685f4d8c5cce96a452793d9f980.pdf

Roger, T., & Johnson, D. W. (1994). *An overview of cooperative learning. Creativity and collaborative learning*. Baltimore, Maryland: Brookes Press.

Roschelle, J. M., Pea, R. D., Hoadley, C. M., Gordin, D. N., & Means, B. M. (2000). Changing How and What Children Learn in School with Computer-Based Technologies: The Future of Children. *Children and Computer Technology, 10*(2), 76–101.

Rotherham, A., & Willingham D. (2009). *21st century skills: The challenges ahead*. Retrieved from http://www.ascd.org/publications/educational leadership/sept09/vol67/num01/21st-Century-Skills@-The-Challenges-Ahead.aspx

Satterthwait, D. (2010). Why are'hands-on'science activities so effective for student learning?. *Teaching Science*, *56*(2), 7–10.

Shernoff, D. J., Csikszentmihalyi, M., Shneider, B., & Shernoff, E. S. (2003). Student engagement in high school classrooms from the perspective of flow theory. *School Psychology Quarterly*, *18*(2), 158.

Sterbinsky, A. (2002). *Rocky Mountain School of Expeditionary Learning Evaluation Report*. Retrieved from http://www.elob.org/evidence/success/RMSEL-crep.pdf

Tamin, R. (2011). What forty years of research says about the impact of technology on learning: *A second-order meta-analysis and validation study. American Educational Research Association.* Thousand Oaks, CA: Sage.

The Education Alliance. (2006). *Closing the Achievement Gap: Best Practices in Teaching Mathematics.* Charleston, WV: The Education Alliance.

Thomas, J. (2000). *A review of research on project-based learning*. Retrieved from http://www.bobpearlman.org/BestPractices/PBL_Research.pdf

Thomas, J. W., & Mergendoller, J.R. and Michaelson, A. (1999). *Project-based learning: A handbook for middle and high school teachers*. Novato, CA: The Buck Institute for Education.

Vega, V. (2012a). *Project-based learning research review.* Retrieved from http://www.edutopia.org/pbl-research-learning-outcomes

Vega, V. (2012b). *Project-based learning research: Avoiding pitfalls*. Retrieved from http://www.edutopia.org/pbl-research -avoiding-pitfalls

Vega, V. (2012c). *Research-supported PBL practices*. Retrieved from http://www.edutopia.org/stw-project-based-learning-best-practices-new-tech-research

Waalkens, M., Aleven, V., & Taatgen, N. (2013). Does supporting multiple student strategies lead to greater learning and motivation? Investigating a source of complexity in the architecture of intelligent tutoring systems. *Computers & Education*. *60*(1), 159-171.

Wright, S. (2012). *Why I love project-based learning*. Retrieved from http://shelleywright.wordpress.com/2012/01/19/why-i-love-project-based-learning/

Yates, C. (2012). *Engaging the relunctant student to learn*. Retrieved from http://virtualicteltpd.ning.com/profiles/blogs/engaging

Yeung, B. (2008). *Put to the test: Confronting concerns about project learning*. Retrieved from http://www.edutopia.org/project-learning-implementing-challenges-questions