THE EFFECTIVENESS OF PROBLEM-BASED LEARNING IN THE HIGH SCHOOL SCIENCE CLASSROOM

A Thesis by

Teresa M. Sindelar

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The following faculty members have examined the final copy of this thesis for form and content, and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Education with a major in Curriculum and Instruction.

Jeri Carroll, Committee Chair

Daniel Bergman, Committee Co-Chair

Judith Hayes, Committee Member

Wally Axmann, Committee Member

DEDICATION

To Grandpa Ferraro, I hope I made you proud

Knowledge is power.

ACKNOWLEDGMENTS

To my wonderful students who agreed to be my guinea pigs without complaint, and found ways to challenge me and make me laugh all in one class period. You all are fantastic learners and I can't wait to see what wonderful truths you will uncover in your lives. To my parents who supported me through all my endeavors. You were my first and best teachers. To USD 313, specifically Jana Moler and Mike Berblinger, for your constant support and guidance. To Dr. Frank Ferraro for reading and re-reading my work. Your perspective taught me so much about learning and about myself. I am forever grateful. To my mentor; the fabulous Dr. Carroll. I never would have made it through without you. You challenged me to think in new ways and gave me a push when I needed it. Next to the definition of "teacher" in the dictionary, there is a picture of Dr. C. Thanks to my other committee members, Drs. Hayes, Axmann and Bergman, for your time, talents and insights. Through your knowledge and experience, you have sculpted me to become a better researcher and a better teacher. To my wonderful husband, Dan, your constant support and contribution give me new ideas every day. Thanks for your patience and understanding with this endeavor. You are the best person I know. Finally, to my children, Mason and Layla, your lives are constant discovery and it warms my soul to see your little "light bulbs" go off. You two are my favorite students.

ABSTRACT

In today's classrooms, students are asked to problem-solve their way through the curriculum in order to enhance their learning. Problem based learning (PBL) is a great strategy when put into practice with guidance and clear objectives. In this study, eighteen Earth/space Science students were exposed to the strategy of PBL. These students' pre and post-assessment scores were then compared to sixteen students in a different class where direct instruction techniques were used. For the research strategy, the instructor changed the focus of the classroom toward the students, and called upon them to be accountable for their own learning using the strategies of problem-based learning. Although some students were uncomfortable with this strategy and struggled to complete tasks when asked to manage their time by themselves, others thrived on the freedom to make their own choices their learning. This study was piloted in the 2008-2009 school year and many modifications were made in order to improve the experience for the students and ensure mastery of the content. Both the control and the experimental groups gained content knowledge throughout the course of the research. The experimental group was also observed to be more engaged in the learning process due to the problem-based learning strategies. The conclusion of this study found that problem-based learning is an effective strategy to use in the classroom, especially regarding student engagement.

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LIST OF ABBREVIATIONS / NOMENCLATURE

AYP – Adequate Yearly Progress

BHS – Buhler High School

PBL – Problem-Based Learning

IEP – Individualized Education Plan

ESL - English as a Second Language

MI – Multiple Intelligences

ANOVA – Analysis of variance (univariate)

PBLI - Problem Based Learning Initiative

PBLN - Problem Based Learning Network

CHAPTER I

INTRODUCTION

They were stranded over 150,000 miles from home in a broken spacecraft. There had been an explosion, their life-giving oxygen was venting into outer space, and time was running out. This was the call that Mission Control in Houston received from veteran astronaut Jim Lovell on Day 2 of the 13th Apollo mission to the moon. What started out as a typical, even routine, mission turned into a potentially disastrous situation with these simple words from uttered from space by Lovell, "Houston, we have a problem" (Lovell & Kluger, 1994).

In the high-tech world that we live in today, the need for problem-solving skills is essential. Employers are searching for graduates who not only have the academic drive to do well in school, but the ability to take on a task that may or may not have an "answer". When the oxygen tank ruptured on the Odyssey Command Module, there was no quick fix, no checklist detailing procedures and certainly no textbook answer to that problem. In his book, *Lost Moon*, astronaut Jim Lovell emphasized the importance of being able to resolve a contingency that is not expected, a skill known in the NASA world as “working the problem” (Lovell & Kluger, 1994). It is this type of the "outside of the box" thinking that gives rise to most major scientific discoveries and the advances in current technology that the world craves. It is this type of problem solving that ultimately saved the lives of the Apollo 13 crew.

Classrooms today are often dictated by state standards and assessments. This is not always a negative, but it is important to remember the big picture. The goal is for students to graduate with a well-rounded education having developed the skills to be successful in the next phase of their lives. Students need to learn how to read and interpret information, not just how to make an educated guess on a multiple-choice test. Learning how to think and problem-solve is the point of education. State standards and school assessment plans clearly dictate what must be taught in any classroom. Most of the material required by the Kansas state standards is valid, important information that students should know before they leave the high school classroom. The question then arises; is it possible to teach the required standards and prepare the students for the state assessments, all the while teaching them problem-based learning skills that will prepare them for life?

In the classroom, students take notes, practice, do an activity, review and are assessed. This is a typical cycle for almost any classroom, no matter the subject. Instead of being engaged and solving the real-life situations of their generation, students are getting bored in school. In an attempt to make classrooms more “inquiry friendly” students perform labs or hands-on activities, watch videos, partner with other students to reflect, etc. But most of these learning formats still do not provide a genuine student-centered classroom. Laboratory experiences turn into "cookie cutter" activities to ease the preparation stress on the teacher and then fall short of true investigations. True inquiry-based learning techniques have been proven to heighten the interests of students during school and provide content knowledge at the same time (Colburn, 2000).

Purpose of the Study

Problem-based learning states that it is possible to teach the content through real-life scenarios without having the traditional notes, practice, activity, assessment cycle. Problem-based learning also claims that students will be more engaged in the process. The question for this research presents itself as; is PBL more “effective” in science classrooms in terms of engagement and retention of content knowledge than traditional direct instruction methods? “Effective” meaning students are actively engaged during the learning process by displaying a certain set of behaviors and they must be able to produce correct answers on a content knowledge post-assessment.

This study was piloted in the 2008-2009 school year and the researcher choose to modify the original idea and combine some strategies of direct instruction and problem-based learning to create an effective learning environment. For the 2009-2010 school year, this researcher believes that students exposed to modified problem-based learning strategies will be more engaged and retain more content knowledge than those students exposed only to direct instruction.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

Problem-based learning is a fairly new idea and is the latest buzzword in education. In the Buhler District, the phrase for PBL is equated to the phrase "Science is a verb", meaning the students should be actively engaged in inquiry and problem solving processes on at least a weekly basis. Problem-based learning gives students the opportunity to experience the curriculum beyond the four walls of the classroom and discover scientific truths for themselves. Students, and often teachers, involved in this process initially feel uncomfortable with this type of learning and can be confused if the expectations are not clearly explained. As uncomfortable as it may be, research has claimed the obvious correlation between student engagement and content retention when using PBL (Barnes & Bramley, 2008). Barnes & Bramley (2008) concluded “making activities relevant to students’ lives, affording students choice in their work, and encouraging students to set goals and reflect on them positively influences engagement in classroom activities” (p. 75).

Inquiry-based Instruction

Inquiry-based instruction is a methodology born out of the Constructivist idea that all learning should occur at the hands of the student (Tenbrink, 1999). As claimed in the article, “We Want to See the Teacher”, any knowledge gained will be more meaningful if the student is allowed to acquire that knowledge first hand (Baines & Stanley, 2000). According to constructivist thinking, "knowledge is personal, and arises out of experiences and interactions which are unique to each individual" (Alkove & McCarty, 1992, p. 18). This idea morphed into what science educators refer to as inquiry-based instruction.

This type of methodology is defined in the *National Science Education Standards* as:

> Science teaching must involve students in inquiry-oriented investigations in which they interact with their teachers and peers. Students establish connections between their current knowledge of science and the scientific knowledge found in many sources; they apply science content to new questions; they engage in problem solving, planning, decision making, and group discussions; and they experience assessments that are consistent with an active approach to learning (National Research Council, 1996, p. 20).

While this is a rather broad definition, it certainly applies to this study. Colburn (2000) offers several different approaches to inquiry-based instruction. This study seems to fit well with the definition of guided inquiry. Guided inquiry is where "the teacher provides only the materials and the problem to investigate. Students devise their own plan procedure to solve the problem" (Colburn, 2000). This study is designed to investigate the effectiveness of PBL, a form of inquiry-based instruction, in the high school science classroom.

Definition of Problem-Based Learning

Problem-based learning is a natural daughter product of inquiry-based instruction. Originally PBL was used in medical and dental schools to help prepare students for future patients (Barrows, 1998).

Barrow (1998) stated that there are 5 guiding principals for PBL.

> *Problem-based*. It begins with the presentation of a real-life (authentic) problem stated as if it might be encountered by practitioners
> *Problem-solving*. It supports the application of problem-solving skills required in "clinical practice". The role of the instructor is to facilitate the application and development of effective problem-solving process.
> *Student-centered*. Students assume responsibility for their own learning and faculty act as facilitators. Instructors must avoid making students dependent on them for what they should learn and know.
> *Self-directed learning*. It develops research skills. Students need to learn how to get information when it is needed and will be current, as this is an essential skill for professional performance.
> *Reflection.* This should take place following the completion of problem work, preferably through group discussion, and is meant to enhance transfer of learning to new problems.

Since the 1960's, PBL has been adapted for use in secondary education as well (Kenny, Bullen, & Loftus, 2006). The definition used in this study is from John Savery (2006) and is stated as "PBL is an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" (p. 12). Another definition that is appropriate for this study comes from Duch, Groh, and Allen (2001) who describe the methods used in PBL and the specific skills developed, including "the ability to think critically, analyze and solve complex, real-world problems, to find, evaluate, and use appropriate learning resources; to work cooperatively, to demonstrate effective communication skills, and to use content knowledge and intellectual skills to become continual learners" (Duch, Groh, & Allen, 2001). These definitions are the guiding theories behind the research in the Earth/space classroom for this study.

Fundamentals of Problem-Based Learning

Problem-based learning has a few basic principals that have been outlined in several research articles. Currently, PBL has been successfully used as an instructional strategy in high schools (Savery & Duffy, 2001). Savery & Duffy (2001) suggest several instructional principals for problem-based learning to be effective (p. 7). Among these principals are setting the stage with an authentic scenario and giving the students the opportunity to come up with their own unique solutions.

Another pair of researchers, Ash and Kluger-Bell (n.d.), suggest eight principals for guiding the use of PBL in the classroom (p.80).

These principals, in order, are:

1. Students View Themselves as Active Participants in the Process of Learning
2. Students Accept an "Invitation to Learn" and Readily Engage in the Exploration Process
3. Students Plan and Carry Out Investigations
4. Students Communicate Using a Variety of Methods
5. Students Propose Explanations and Solutions and Build a Store of Concepts
6. Students Raise Questions
7. Students Use Observations
8. Students Critique Their Science Practices

This model goes hand-in-hand with the scientific method as part of the fundamental concepts required in any Science classroom (Ash & Kluger-Bell, n.d.) and as required by the Kansas via the State Standard: Science as an Inquiry.

Why use PBL?

PBL offers many positives for students in the classroom. While it is not the only way to teach students, it does offer a positive environment for sincere problem solving without restricting the students' ideas to the confines of one school of thought. There are several fundamental reasons to use this strategy in the classroom: increases motivation, promotes higher order thinking, metacognition and self-regulated learning all while making learning relevant to real-world situations (Torp & Sage, 2002). Of those reasons, motivation and higher order thinking are the foci if this research study.

PBL is so popular there are entire institutions dedicated to the promotion of this strategy. The thinking behind this is that students who learn how to use PBL early in life will be more successful in their careers simply because of their ability to work through difficult situations. The Problem-Based Learning Initiative's (PBLI) mission is to help teachers produce "independent learners who can continue to learn on their own in life and in their chosen careers" through PBL (www.pbli.org). Also, there is the Problem-Based Learning Network (http://pbln.imsa.edu/index.html) that also offers resources and opportunities for educators and students to become well versed in PBL.

Teachers Role in PBL

Although a teacher's role in the classroom changes daily, PBL offers a specific set of challenges for teachers in order to accomplish the goals of PBL. In order for teachers to be successful in creating a genuine PBL environment, teachers must first "support inquiry-based instruction" (Colburn, 2000). Once that is established, teachers will need to continually evaluate and adapt to the ever-changing environment of PBL as seen in the cyclic diagram of Figure 1. Clark, et al (2000) suggest that "with well-phrased questions, the teacher can guide students to see discrepancies in their thinking and consider alternatives without telling them exactly what to do" (p. 42). Figure 1 from Torp & Sage (2002) displayed on the Problem-based Learning Network's (PBLN) website shows the dual roles teachers must play when creating an effective and genuine environment.

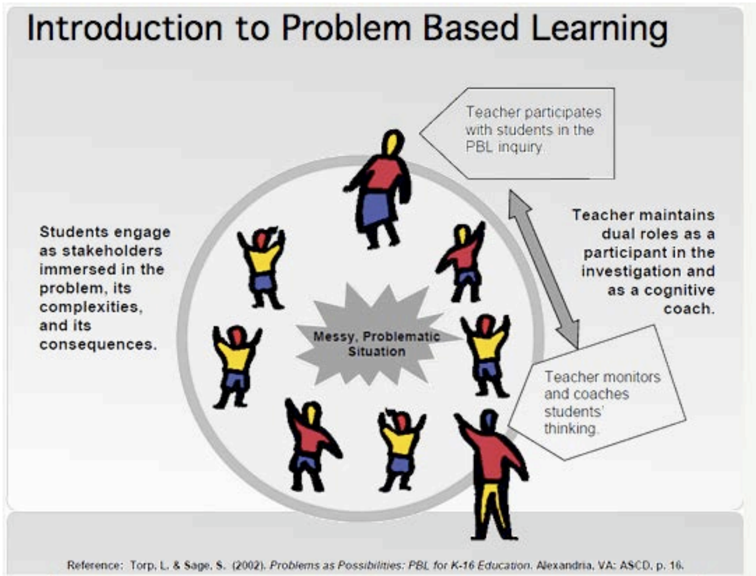

Figure 1. Introduction to PBL (Torp & Sage, 2002).

Many teachers stray away from PBL simply because it requires a lot of preparation time and then a lot of time walking the room making sure the students are following the PBL model as shown in Figure 1. For this study, the instructor adopted the role of "a facilitator or educational coach (often referred to in jargon of PBL as a 'tutor') guiding the learners in the PBL process. As learners become more proficient in the PBL learning process the tutor becomes less active" (www.pbli.org). The Problem-Based Learning Initiative (PBLI) offers a variety of workshops and professional development opportunities for teachers who wish to become more versed in PBL, as it is quite a change from traditional teaching methods. Colburn (2000) states that there are identified behaviors that a teacher must exhibit (or not exhibit) in order to encourage problem-solving skills in students.

Colburn (2000) suggests teachers in a PBL atmosphere should:

1 – Ask open-ended questions
2 – Wait for the students to respond to those questions and give time to process
3 – Repeat or paraphrase student ideas, but don't criticize
4 – Don't tell the students exactly how to do something
5 – Manage discipline/behavioral problems, as always

Just as this type of strategy may not effective for every student, PBL is not for every teacher. Teachers must make a commitment to the curriculum and the process of PBL in order give the students the opportunities to be successful. The PBL classroom is not one where worksheets are handed out and the teacher stays at his/her desk while the students work silently. Nor is it a classroom where the students are unfocused and unsure of how to complete a project so chaos ensues. “Effective teaching (in PBL) is a highly interactive activity” where teachers are key to the structure of the PBL classroom, giving way to enhanced student engagement, and increased content knowledge (Clark, Clough & Berg, p.42).

Direct Instruction Versus Problem-Based Learning

Direct instruction typically refers to an instructional strategy in which the learning environment is teacher-driven and tends to limit student engagement. A typical view of this strategy would consist of students in their seats, passively taking notes as the teacher stands in front of the class. Problem-based learning offers a different strategy to combat the lack of student engagement and enhance student learning by giving the students the power over their learning. Figure 2 from the Problem-Based Learning Network describes PBL as “an experience” as opposed to a pre-determined path of curriculum.

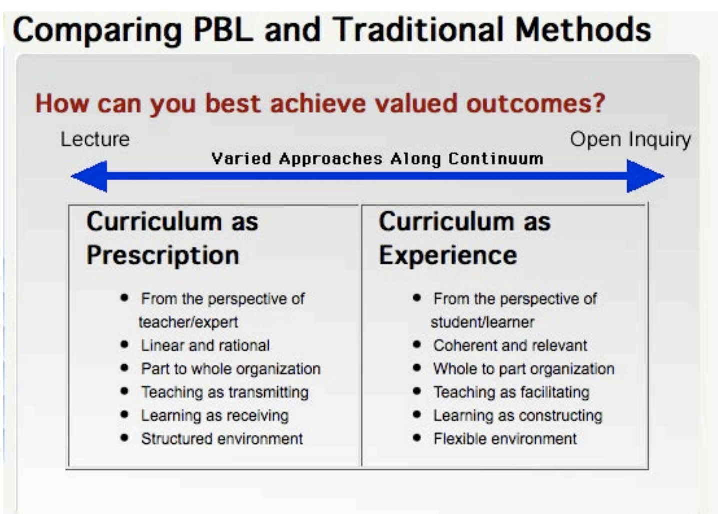

Figure 2. PBL as an experience.

Sungar (2006) suggests:

> "that high school teachers use PBL to improve students' academic performance by going beyond teaching content to teaching students how to learn. PBL is different from other instructional strategies because it places students in the center of an authentic, ill-structured problem with no correct answer" (p. 316).

Once students realize they are in control of the outcome, motivation and engagement tend to increase.

PBL is an exciting strategy to use in class. However, students also need an informational foundation, often provided by direct instruction, in place before attempting these PBL strategies. In one PBL study, Gurses et al. (2007) never saw a *drastic* change in the students' attitudes toward the curriculum, but direct instruction was at times favored because of its familiarity.

Even though this study is focusing on PBL, direct instruction has its place in the classroom. For example, research indicates, "direct instruction has been shown to be an efficient way to teach procedures that are difficult for students to discover on their own" (Anderson, Corbett, Koedinger, & Pelletier, 1995; Klahr & Carver, 1988). In fact, one research study profoundly challenges the superiority of all inquiry-based learning. Authors Klahr and Nigam (2004) vehemently argue this point and conducted an entire study in which they "question the widely accepted view that discovery learning usually trumps direct instruction" (p. 1). Teacher-centered classrooms provide a good amount of general knowledge and provide some avenues for engagement. However, most teacher-centered classrooms leave students as passive subjects rather than active learners.

Teachers today are faced with enormous challenges to meet annual yearly progress (AYP) and complete the intended curriculum in an increasingly busy school year. At times, direct instruction seems to be the easier way to teach students in a time crunch. Many teachers find problem-based learning to be cumbersome and take too much time away from teaching the required curriculum. The key to problem-based learning is the inquiry process *replaces* the direct instruction time in the classroom. This is a concept that may cause teachers and students alike to be uncomfortable. Students want to be spoon-fed and teachers want to "cover" all the material necessary for the state assessments, school required curriculum and standards. Finding a balance between the two is key in creating a successful classroom.

It is up to the teacher "to find the right mix of inquiry and non-inquiry-based method that engages students in the learning process" (Savery, 2000, p.44). However, it has been documented by Mitchell et al. (2009) that working on problem-based scenarios "can promote students' development and application of new skills, standards, and knowledge in a variety of contexts as they work" (p. 340) giving rise to the possibility that not every lesson needs to be taught word for word by the teacher.

Problem-Based Learning Versus Project-Based Learning

In many cases researchers, teachers, students and administrators confuse the idea of problem based learning with another popular concept: *project*-based learning. Although both types of learning involve the inquiry methodology of teaching, problem-based learning gives the student the opportunity to answer a question or offer multiple solutions. On the contrary, project-based learning allows the students to create a product to showcase their inquiry skills (Colley, 2008). Most of the time, these two strategies are hybrids of one another. For example, in project-based learning, students may be asked to create a product using just the materials provided *and* solve a problem at the same time. In a famous scene in the movie *Apollo 13*, this type of learning is beautifully displayed. One NASA engineer dumps out an entire box of materials on a table. These are the only available materials the astronauts have on board the crippled Apollo 13 spacecraft. He instructs his team that they need to find a way to make a square filter fit into the round hole, using nothing but what they have in front of them (Glaser, Lovell, Kluger, Broyles, Reinhert & Howard, 1995). These engineers are asked to solve a problem: lower the rising Carbon dioxide levels onboard the spacecraft, and create a product, the filter, in order to save the lives of the crew.

While project-based learning and problem-based learning are close relatives, there are clear differences in the two instructional approaches. The process of problem-based learning "begins with students being presented with an authentic problem to be solved. The problem may be posed by an industry or business partner, or fabricated by an instructor based on real-world events and data" (Massa, 2008, p. 19). Massa (2008) goes on to suggest the students then brainstorm and come up with a unique solution for their proposed problem. However, students are not required to build or design a product at the end of the lesson. If time is an issue, the PBL environment can stop once the solution is presented. It's the skills gained, rather than the production of a physical object, that differentiates between the two strategies.

In his research, Beringer (2007) concluded that PBL was too cumbersome for his students to grasp and instead modified the PBL activity with more structure, increased guidance from the teacher, and shifted to a more project-based approach. This shift allowed the instructor to be more involved in the creation of a project and made the students who were worried about "disorganization" feel more comfortable (Beringer, 2007, p. 455). In this researcher's opinion, project-based learning is a natural extension of PBL. Once the students have come up with a solution, have them construct it. Then, if possible, test it to see if it supports their conclusions. There is no better way to learn than to see your own creation through the entire scientific method process. That's why stories like that of the ill-fated voyage of Apollo 13 are so popular.

Limitations of PBL

There are, however, some limitations to the PBL approach. In their research, Akinoglu & Ozkardes-Tandogan (2007) identified several factors that can limit PBL in the classroom (p. 74).

- It could be difficult for teachers to change their teaching styles.
- It could take more time for students to solve problematic situations.
- Groups or individuals may finish their works earlier or later.
- Problem based learning requires rich material and research.
- It is difficult to implement problem based learning model in all classes. It is unfruitful to use this strategy with students who could not fully understand the value or scope of the problems with social content.
- It is quite difficult to assess learning (Dincer & Guneysu, 1998; Treagustm & Peterson, 1998; Kalayci, 2001; Senocak, 2005).

Gurses et al. (2007) concluded that research shows that the initial transition from a traditional to a PBL curriculum may be a difficult adjustment for students (p. 107). The adjustment is difficult because students are often concerned about content coverage in PBL environments (Dods, 1997; Lieux, 1996). The students, at times, struggle with how to discern what information is supplemental in the problem and what is deemed "important" information for them to know for the test. Furthermore, they struggle with how to bridge the gap between what they investigated in the scenario and what principals are required for the class. These two should go hand in hand. Whatever the students learned in class previously, should be a fundamental part of solving the problem they are given. Overall, their concerns mostly relate to uncertainty about their grades (Woods, 1996). Students like to know exactly how much they have to do in order to receive a certain grade. Putting them in roles where they are evaluated in several different ways and where “right” and “wrong” no longer matter, tends to makes some students apprehensive. This might be due to the newness of students’ roles in PBL or the difficulty of changing their attitudes about the class, the teacher, themselves and the learning process itself (p. 107). Despite all these issues, students in this researchers classroom still produced understandable solutions to a problem and most of them were able to relate that information gleaned in the process back to the content of the class.

There are a common sense ideas that help make PBL successful in the classroom. Students need to feel like what they are doing in school is both meaningful and relevant to their lives (Mitchell et al. 2009). This can be applied to students in an elementary classroom all the way through graduate school. If students don’t see the point, then why do it? It’s all about making connections and keeping the students involved and thinking of solutions without forcing a topic upon them that has no genuine meaning. In order for PBL to be seen as important, teachers must find a way to introduce problems that are relevant and timely to the students in today’s classrooms. Despite its “problems”, pardon the pun, the strategy of PBL offers an interesting and engaging alternative to the traditional classroom instructional techniques.

Conclusions

The nature of teaching requires the instructor to be able to adapt to different learning styles, and use a variety of pedagogical techniques to reinforce certain concepts. Sometimes PBL is the answer, and other times direct instruction is the way to go. Teachers may find it is best to use a combination of the two to provide an effective and engaging learning environment. This is usually a trial and error process, one that requires teachers to continually adapt in order to provide all students with the best possible opportunity to be successful. The art and science of teaching is that in order to teach problem solving skills, one must model the very concept.

CHAPTER 3

METHODOLOGY

Participants

All research took place in the co-researcher's classroom in the Unified School District (USD) #313. USD 313 believes all students and staff will excel in a safe, caring and collaborative environment. The community of USD 313 is committed to student learning and emphasizes collaboration, communication and professional development. USD 313 (also known as "Buhler") is located in the middle of Reno County, KS. USD 313 is a district that consists of 4 elementary schools, 1 middle school and 1 high school. This research study took place in the secondary science classroom at Buhler High School. USD 313 has mainly Caucasian students with about a 50/50 ratio of males to females. USD 313 typically serves students with middle to upper level socio-economic status and from white, two-parent families with good socioeconomic standings. However, 4% of the student population is Hispanic, approximately 3% is African American and another 3.5% are classified as "other" (http://online.ksde.org/rcard/bldg_enr_race.aspx?org_no=D0313&bldg_no=3254). In the district, 33% of all students have been identified as economically disadvantaged, there is only 1.3% of students who are English Language Learners and 10.38% of students in the district have been receiving assistance because of disabilities (http://online.ksde.org/rcard/building.aspx?org_no=D0313&bldg_no=3254). The mission statement that *every student can learn* is one that is put into practice daily at Buhler High School. Most of Buhler's students attend class regularly and among the 630 students, there are minimal discipline problems. The graduation rate in 2008 was excellent at 92.5% and our overall attendance rate was 95.2% for 2009 (http://online.ksde.org/rcard/bldg_attend.aspx?org_no=D0313&bldg_no=3254).

The students that participated in this study attend Buhler High School (BHS). Unlike the majority of USD 313 schools, BHS is located in the small town of Buhler, KS (population 1300). The classroom is a classic science lab. Students are verbally informed of the daily procedures, which are written on the board as well. Students are given the opportunity to build productive relationships in class, but also are aware that they are expected to work hard and be accountable. This classroom has a plethora of technological and physical resources. The classroom has a laptop computer, a digital projector, several whiteboards, two closets full of supplies, an abundance of lab equipment and a class set of new textbooks as well. There are twenty dedicated laptop computers in the science department at the students' disposal. Buhler has a district technology department that has a variety of media and equipment such as iPods, microphones, video cameras, computers, etc that could be used in the classroom any time to support PBL.

Research Group

For the purposes of this study this group will be referred to as Group 1. The participants in Group 1 consisted of eighteen students; two sophomores, fourteen juniors and two seniors in an Earth/space science classroom. Each student within this group was given a number. The numbers vary from 1 – 18.

Demographics. Of the eighteen students, there are five females and thirteen males. The ethnicity of the group is fairly homogeneous. Fifteen of the eighteen students are Caucasian/White, two are Hispanic and one is Indian.

Overall, this class is a very social group, but have a good measure of self-control for high school students. Students are usually very punctual and are ready to work. Although there are regular absences in this class, the students generally have a good attitude when they walk through the door. Several students in this class need daily reminders and coaxing to complete assignments, and keeping focus throughout the class period can be a challenge.

Special Needs and Accommodations. The needs of the students vary in this classroom. Most students are highly functional and the mean of the class is a 79% (C+). There are four students on IEP's in this class. One of these students has a history of seizures and a recent head injury. He has difficulty with reading comprehension and is only responsible for 50% of the course content. This student has accommodations provided for him and his assessments are reduced in terms of length and in number of concepts he is responsible for. Of the 50% of the coursework he is responsible for, the instructor determines what content can be eliminated and what is essential for him to learn.

Other special considerations include one male student with moderate hearing loss in addition to his learning disability and two others (one male, one female) with significant learning disabilities. All identified students are allowed more time on assignments and offered additional help organizing and prioritizing schoolwork as well as the typical accommodations on assessments and assignments. Typical accommodations include only three possible answers for multiple-choice questions, word banks provided for fill-in-the-blank assessments, having the test read to the student and more time allotted for assessments and/or projects. There is also a para professional available in the classroom for these students as well. Other students with special consideration are one female with attendance issues because of health concerns and one male diabetic.

Multiple Intelligences Survey. It can be said, after giving the students a multiple intelligences survey from McKenzie (1999), that the students overall have a few dominant characteristics. The survey had a series of ten statements for each type of intelligence. Students ranked the statements they felt accurately described them. After all the intelligences were accounted for, the students then calculated their score and determined where their intellectual strengths and/or interests lie. The researcher then took the average of the entire class, by intelligence. As seen in Figure 3, those learning styles that are most dominant in Group 1, meaning they had a score of 7 out of 10 or above, are kinesthetic, intrapersonal, and visual.

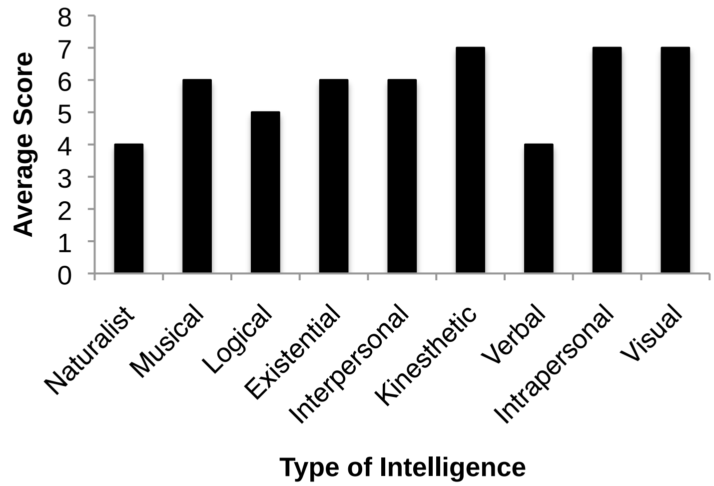

Figure 3. Multiple intelligence indicators for Group 1.

This data indicates that most students need to be stimulated through projects using different sights and want to take an active role in their learning. These intelligences lend themselves well to PBL. The hands-on component is engaging for kinesthetic learners, the creation of a product is stimulating to a visual learner and the PBL model is based on self-reflection and the students taking it upon themselves to find a solution, which is appealing to intrapersonal learners. The different ways these students learn play an important role in designing and implementing the PBL strategies.

The greatest challenges in Group 1 revolve around attendance and motivation. Students who are in regular attendance tend to have the highest scores on the assessments. Students who are absent frequently struggle with not only the course content but they tend to lose motivation then find it difficult to pull out of a downward spiral once their grades begin to suffer. The other difference among students in Group 1 is the motivation factor. All of the students in this class are capable and intelligent enough to excel; it is simply a matter of effort and desire. In an attempt to try to increase both their understanding and their desire to learn, the instructor typically challenged them with hands-on activities and projects throughout the year. This is also to prepare them for this research project. PBL tends to increase the level of interest for these hands-on, active learners. Byer (2001) found that students who experience a connection between what they are learning in the classroom and the important aspects of their lives tend to have a more positive outlook on other educational experiences. Using PBL strategies to keep them stimulated was a creative way to engage their minds to learn the material and motivated them to do well at the same time.

This group is highly inquisitive and has a genuine understanding of the topics covered thus far in class. There are no behavior issues to date. Most of the students are interested in the material and enjoy hands-on projects. This class tends to be very social so staying on task can be an issue as can time management when it comes to deadlines. They are learning, from previous experience, how to make the most of the time given to them and how to operate as a functional group. The instructor has strategies to help them with this, such as checkpoints along the way, group and individual accountability conversations and grading the parts of the project separately (participation, presentation, lab write up, etc).

Based on previous scores on class assessments, the students are at or above grade-level in their understanding of analytical concepts. The 7th and 8th grade science teachers in this district concur with those statements. According to the Kansas Department of Education (2007) 74% of students in this class scored at or above standard in 2008 on the math state assessment. This is the best indicator for the present time. Since science was not yet tested, these scores for math indicate these students have a decent level of comprehension of the analytical processes and concepts used in both math and an upper level science class. (http://online.ksde.org/rcard/bldg_assess.aspx?assess_type=2&org_no=D0313&bldg_no=3262&grade=08&subgroup=1). The juniors in this group (the majority) will be tested the first week in May on the State Science Assessment. Students' skills and prior learning are displayed frequently when questions are asked in class and the students respond appropriately. Compared to other Earth/space Science classes, Group 1 overall has a high level of comprehension based on class assessments (quizzes, tests, in-class assignments). This is reflected in their grades and the average for the entire class is a 79% (C+). These students are not the highest class, but are not the lowest either. They rank on right in the middle with the other Earth/space Science classes at Buhler High School.

Control group

For the purposes of this study this group will be referred to as Group 2. The participants in Group 2 consisted of sixteen students; three sophomores, ten juniors and three seniors in an Earth/space science classroom. The same numbering system has been used as with Group 1. The students in 4th Hour are assigned numbers from 1 – 16.

Demographics. Of the sixteen students, there are seven females and nine males. The ethnicity of the group is completely homogeneous. All students are Caucasian/White, there are no are Hispanic students or ESL students.

Special Needs. There is one student on an IEP in this class. She struggles with reading comprehension and needs clarification on assessments. There is a para professional in the class to accommodate her needs. However, her reliance on these accommodations is minimal and she is very well adjusted into the mainstream classroom.

Methods

Pilot Study

This study was piloted in the 2008-2009 school year. This study hypothesized that students in the PBL group would gain more knowledge than the group exposed to direct instruction. The pilot study lasted one week. A pre-assessment was given to the two groups that were studied: a control group that was exposed to direct instruction only and a research group was exposed to the problem based learning strategies. All students took the same pre-assessment. After this, the strategies began. Group 1 began with a packet of information and it was their responsibility to study those notes. There was no direct instruction over the notes, but students did have access to the Internet and textbooks for the duration of the unit. The students were put in groups of two or three and assigned their problem scenario. These same scenarios were also used for this thesis research project. The instructor kept a tally and recorded observations throughout the research process. Students then presented a final product. Group 2 started out by watching a video, leading into guided notes about types of volcanoes, locations of volcanoes, viscosity, volcanic risks and prevention. Finally, these students were assigned one volcano to research and created a poster. These students were assessed through a paper-pencil quiz half way through the unit. The posters were then peer graded and graded on a rubric by the instructor.

Both groups then took a cumulative common assessment to determine the amount of knowledge gained. These scores were then compared to the pre-assessment. In this pilot study, it was concluded that students in the PBL classroom did not gain more content knowledge than those subjected to direct instruction. Based this knowledge and further research, the instructor decided to modify the PBL strategies for the 2009-2010 research project.

Modifications from the pilot study

Several challenges presented themselves in the pilot study. One of the biggest challenges faced in the PBL classroom was the fact that several students did not take the project seriously and/or did not know how to manage their time when given such freedom. Once given the freedom to make their own choices in their learning, several choose not to learn at all. Others were confused and frustrated with the lack of specific instructions from the teacher. This could have been avoided if the class had been exposed to PBL strategies earlier in the school year. Then students would understand the expectations and be more comfortable with the PBL environment.

It was also evident that these students did not go into the project with a strong base knowledge, even though students reportedly covered the same material in the middle school science curriculum. Because of the lack of prior knowledge, students never advanced to the higher-level thinking of problem solving or analyzed the material for a deeper understanding. They were simply ignorant of the overall topic to begin with. In order to gain a significant understanding, the student must advance from basic memorization and surface knowledge to the high orders of cognition (Bloom, 1956). Unfortunately, these students were ill equipped to reach that goal.

Based on the results of the pilot study, further research, and input from the thesis committee, the instructor has decided to incorporate some changes into the actual thesis study. In turn, these additions also helped counteract some of the limitations researched by Akinoglu & Ozkardes Tandogan (2007) as mentioned in the Literature Review.

The following modifications were made:

- Use a combination of both PBL and direct instruction
- Use PBL strategies on other projects during the year
- Revise the instructional notes
- Redefine the guidelines for the creation of the product and the presentation
- Set clear expectations, using a checklist, to guide the students
- Have daily conferences with the groups to ensure progress
- Adopt a more open time frame, giving check points along the way
- Allow more access to resources (computers, textbooks, library resources)
- Eliminate the use of a wiki and switch to a more user-friendly Weebly website
- Measure content knowledge gained as well as level of engagement using the PBL model

2009-2010 Research Study

All activities took place in the researcher's classroom while the students were studying volcanoes. The study lasted two weeks. A pre-assessment was given first followed by a common post-assessment. The plan for the intervention included the following: two groups were studied, a modified PBL group and a direct instruction group. Based on the results of the pilot study, a more guided PBL method was used as opposed to pure PBL in order to ensure that the students received adequate background knowledge no matter which group they were part of. Group 1 was exposed to the modified problem-based learning strategies and Group 2 was exposed to only the traditional method of teaching: direct instruction. All students took the same pre-assessment. Both groups started out by watching a video, leading into guided notes (types of volcanoes, locations of volcanoes, viscosity, volcanic risks and prevention). Students in both groups were assessed through a formative paper-pencil quiz half way through the unit and both groups took the same post-assessment after the strategies.

After these guided notes, the PBL strategies began with Group 1, while Group 2 continued with traditional instructional methods. Group 1 students were put in groups of two or three and assigned 1 of 4 different scenarios to study. These scenarios are designed to be problem-based learning activities found online on the Volcanoes Situations Page. They are developed by Wheeling Jesuit University, which is supported by NASA, Classroom of the Future and can be found online at http://www.cotf.edu/ete/modules/modules.html. During their investigations, students performed a viscosity lab and connected that information to the dangers of volcanic eruptions. The students then continued to investigate an impending volcanic eruption, and formulated a solution to their "problem". Students in Group 1 then created a final product. This could have been in the form of a video, a digital poster, a model, a newspaper article, or any other acceptable form. One of the fundamentals of PBL is allowing the students some choices in their learning. Tomlinson (1999) speaks to this when discussing the idea of differentiated instruction in the classroom. PBL is just another avenue where teachers can differentiate. "Differentiation is about high-quality performance for all individuals and giving students the opportunity to develop their particular strengths" (Tomlinson, 1999, p. 24). The everyday differentiation strategy combined with PBL gave students the confidence they needed to create a product that showcased their individual and group talents. Every product created was different. By giving the students this freedom, each product was a reflection of what the students decided was important, not what the instructor dictated. These products were graded on a rubric, as was the 5-7 minute class presentation. These students were assessed on a day-by-day basis. Students were encouraged to ask questions and had multiple resources available to them; however, no "answers" were given to the students as they researched. The teacher recorded student progress and documented student behaviors and engagement level in the form of qualitative field notes.

Instruments

Assessment of student learning and engagement took place on multiple days in multiple ways. Although the teaching strategies differed, major assessment pieces were the same throughout. All classes took the same pre-assessment at the beginning of the unit. All students were assessed by a formative quiz half way through the unit. Once both classes completed all the required elements of their unit, the students took a cumulative, common, post-assessment over volcanoes. The post-assessment was not a replica of the pre-assessment, but the questions asked were designed to test the same concepts as presented in the pre-assessment. The pre-assessment questions were then correlated to like questions and/or concepts on the post-assessment. The results were compared and analyzed for purposes of reporting data.

Common Instruments

Pre-assessment. The pre-assessment consisted of 20 multiple-choice questions. This instrument was designed to determine the amount of previous knowledge the students had and to determine areas where additional instruction was needed. Students took this pre-assessment before any type of instruction took place. In the end, both classes scored about the same on the pre-assessment. Group 1 averaged a 57.8% while Group 2 was a close second with 52.5%. Since the both classes started out on the almost the same level, the end results can be compared accurately. Hopefully offering some real implications on the effectiveness of problem-based learning strategies. See Appendix A for the pre-assessment.

Formative Quiz. The next assessment piece was a formative quiz. This quiz was given to both groups about half way through the unit. The purpose of this quiz was to determine if both groups of students understood the new concepts, although presented in different ways. This quiz was a combination of short answer, multiple-choice, fill in the blank and diagramming the interior of a volcano. See Appendix B for the formative quiz.

Post-Assessment. Finally, all students were assessed using a 55 question multiple-choice common assessment. All students in all classes took this assessment. This assessment covered all the major aspects of the volcanoes unit and was in alignment with the Kansas state standards regarding Earth/space science (http://online.ksde.org). See Appendix C for the post-assessment.

Qualitative Field Notes. All above-mentioned instruments were meant to measure the content knowledge gained by the students over the course of the two-week experience. There is one other crucial piece that must be considered when discussing PBL. The purpose of this study is to research the effectiveness of PBL in terms of content knowledge gained *and* the level of engagement among students in the PBL environment. In order to measure the level of engagement this researcher created a system of qualitative field notes to organize student behaviors. These field notes are based upon conversations and/or actions of the students in both Group 1 and Group 2 and are adapted from Thiede (2004). In this system, the teacher observes the students for an entire class period and records both their verbal conversations and their actions. Then each behavior and/or comment is given a letter/symbol using a code. Students also are observed for on and off task behavior. Table 1 shows a sampling of the qualitative field notes.

TABLE 1

QUALITATIVE FIELD NOTES SAMPLE

Student #	**Comments**	**Codes**	
1		*	On-task
2		--	Off-task
3		A	Assisted by Teacher
4		R	Redirected by Teacher
5		C	Contributed to Discussion
6		D	Disrupted Instruction/Discussion
7		I	Inappropriate Comment
8		U	Unrelated/Inappropriate Talking
9		B	Inappropriate Behavior/Action
10		Q	Asked a Question
11		N	Needed Clarification
12		P	Participated in creating a Created a product

Additional Group 1 Instruments

Viscosity lab. One instrument used in this project was a lab dedicated to viscosity. The students investigated the viscosity of different liquids. The students were asked to investigate the viscosity of three different liquids; maple syrup, light corn syrup and honey. The students filled three, 100 mL graduated cylinders with the liquids. Then the students dropped a marble into each liquid to test viscosity. Next, they measured the amount of time it took for the marble to fall to the 20 mL mark. The calculated viscosity was given in the lab and the students were asked to graph the time it took the marble to fall against the viscosity of the liquid. From there, students were asked to make a connection between the time it took for the marble to fall and the viscosity of the liquid. It was the hope of the instructor that the students would then connect that the more viscous the liquid; the longer it takes the marble to fall. Once that was established, students were then asked to connect the results of this lab to what we know about the viscosity of actual lava. The instructor assessed their results by discussing the questions and having the students produce a graph to promote understanding. Using their previous knowledge, the students then related the data from the lab to the viscosity of magma in an actual volcano. It was determined that no additional instruction was needed in order for the students to relate viscosity to volcanic eruptions. See Appendix D for the viscosity lab.

Checklists. Students in Group 1 were required to sit down with the teacher and give a progress report. This was in the form of a checklist that the students filled out and the teacher initialed. This checklist detailed items the group must understand, items they must prepare and items they must complete. All groups completed this checklist in order to ensure progress and avoid frustrations seen in the pilot study. See Appendix E for the PBL Student Checklist.

Rubrics. Once complete, all products and presentations from Group 1 were graded on a rubric. See Appendix F for assessment pieces for PBL strategies.

CHAPTER 4

RESULTS

This research project was designed to evaluate the effectiveness of PBL. The hypothesis for this research project states that students who were exposed to PBL would 1) gain more content knowledge than those exposed only to direct instruction and 2) would display an increase in engagement in the classroom. If both of these criterion were documented during the research project, then PBL would be said to be "effective" in the science classroom. To evaluate an increase in content knowledge, average pre and post-assessment scores were compared as well as learning gain scores. To quantify an increase in engagement, the researcher analyzed the qualitative field notes and relied on comments and behaviors recorded during the class periods.

Pre vs. Post-assessment Results

Figure 4 compares the average pre and post-assessment scores for both groups. Both classes, on average, showed a failing percentage on the pre-assessment. Group 1 averaged at 57.8% and Group 2 averaged at 52.5%. After the completion of the unit, students then took a post-assessment. These scores were in the "B" range (80-89%) for both groups. Group 1 averaged 82.9% and Group 2 averaged 83.4%. In both cases, the class averages improved from pre to post-assessment.

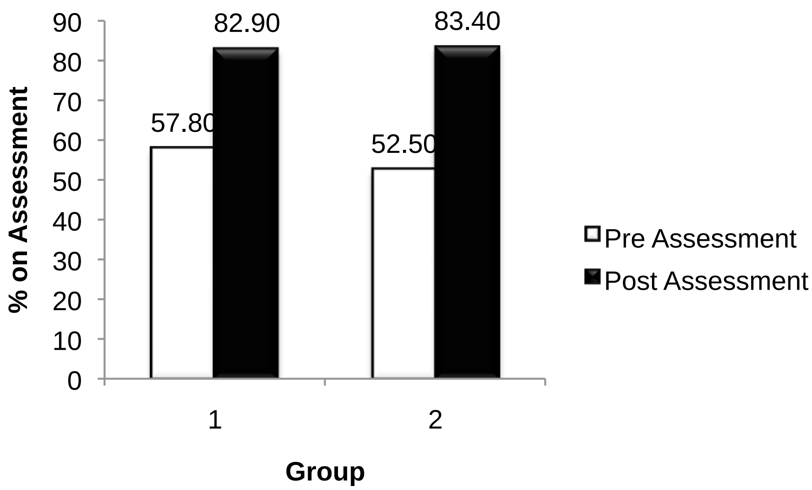

Figure 4. Pre and Post Assessment Results.

Learning Gain Scores

Learning gain scores (LGS) are comparisons between the pre and post-assessment scores of individual students or groups (www.emporia.edu/teach/tws/documents/GainScores.doc). In this process the researcher is calculating "how much the student *actually* gained out of the total possible that they *could* have gained from pre to post-assessment" (www.emporia.edu/teach/tws/documents/GainScores.doc).

The formula used is seen in Equation 1:

$$LGS = \frac{(\text{\% on Post-assessment} - \text{\% on Pre-assessment})}{(100\% - \text{\% on Pre-assessment})} \qquad (1)$$

In this study, the percentages of the pre and post-assessments were used in this formula by dividing "the actual gain (numerator) by the potential gain (denominator)" (www.emporia.edu/teach/tws/documents/GainScores.doc). A large LGS would indicate that a student and/or group gained knowledge from the pre to the post-assessment. The hopeful outcome of this study would be to show an increase in LGS for both the entire group and the individual to substantiate the hypothesis that students exposed to PBL would gain more content knowledge. The ideal LGS for each student would be 1.00, meaning that each student actually gained all of the possible knowledge from pre to post-assessment.

Individual LGS

Group 1. Figure 5 shows individual gain scores for Group 1. Most individuals in Group 1 did show an increase in individual LGS, with the exception of two students. Student scores on the pre-assessment ranged from 40-75% and all of them, with the exception of two, showed an increase from pre to post-assessment. Group 1 had two very low LGS, -.30 and -.13. These scores indicate that those two individuals did not gain any knowledge from pre to post-assessment, and furthermore, may have *lost* some of the original knowledge they displayed on the pre-assessment.

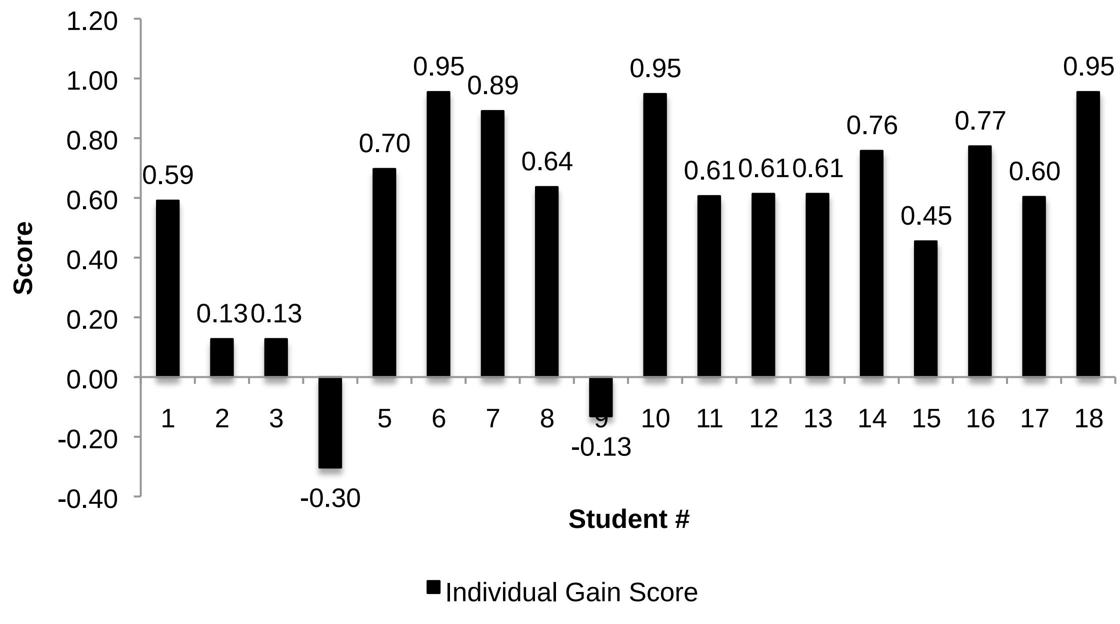

Figure 5. Group 1 individual learning gain scores

Group 2. Figure 6 shows individual gain scores for Group 2. All students in Group 2 had a positive LGS. As seen by Figure 6, the lowest LGS for Group 2 was .34 and the highest was .90. These scores indicate that all students gained a minimum of 34% of the possible percentage points from pre to post-assessment.

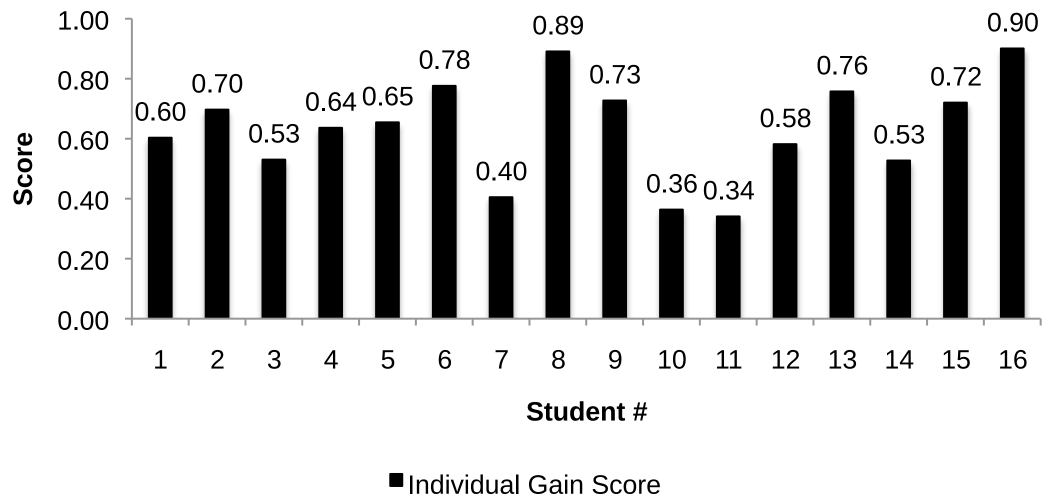

Figure 6. Group 2 individual learning gain scores

Average Group LGS

The average was then taken of the individual LGS for each group. This was done to compare an overall gain of content knowledge between the two groups. Figure 7 shows the average LGS for both groups. Group 1 had an average of 0.472 and Group 2 ‘s average was 0.482. Both groups showed a positive LGS at the conclusion of the unit although Group 2 did show more of a positive increase than Group 1. However, this was only a slight difference of 1.0.

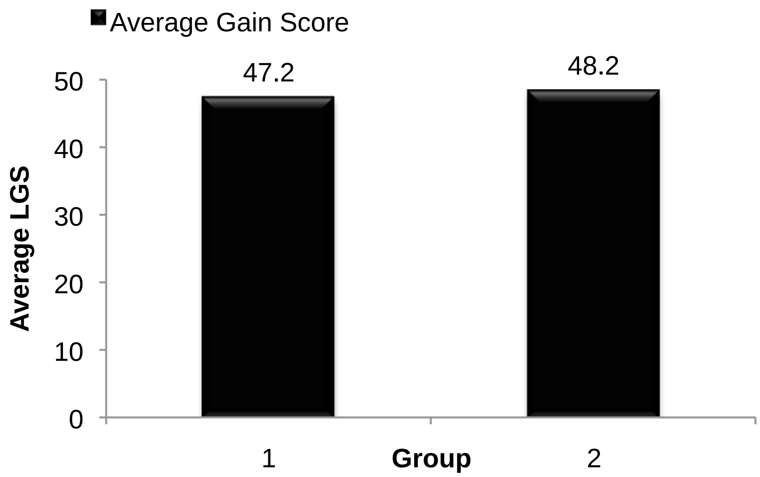

Figure 7. Average LGS for both groups

Qualitative Field Notes Results

In order to assess the engagement of students in the PBL process, the researcher developed a system of observing students then recording and categorizing those observations. This system attempts to measure student engagement by correlating common engaged/non-engaged behaviors with the displayed behavior from the student. For example, an engaged student may ask for clarification, contribute to a discussion among peers or help physically create product. Some non-engaged behaviors observed were students talking about unrelated topics such as prom, spring break or other classes. These students were not multi-tasking (working and talking), but rather ignoring their classroom responsibilities to have an unrelated conversation. The most obvious non-engaged behavior is displayed when students are performing an action that is not in accordance with the requirements of the project and many times violates classroom rules. One of the issues with PBL is allowing students to manage their own time. Some students are unable to discipline themselves enough to have that kind of freedom (as a side note, many of my students argued they were in fact engaged in their behavior, albeit inappropriate). Table 2 defines the differences between engaged and non-engaged behaviors.

TABLE 2

ENGAGED VS. NON-ENGAGED BEHAVIORS

Engaged Behaviors	**Non-Engaged Behaviors**
Assisted by teacher	Redirected by teacher
On task	Off task
Asked a Question	Disrupted Instruction/Discussion
Needed Clarification	Inappropriate Comment
Participated in creating a product	Unrelated/Inappropriate Talking
Contributed to Discussion	Inappropriate Behavior/Action

Students were observed during each class period for the entire ten-day research project. Figures 8 and 9 display engaged vs. non-engaged behaviors, and take into account students who were absent for each day.

Figure 8 shows that over the ten-day research period, the majority of the eighteen students in Group 1 consistently displayed engaged behaviors. Adversely, students in Group 2 consistently displayed non-engaged behaviors throughout the project as seen in Figure 9.

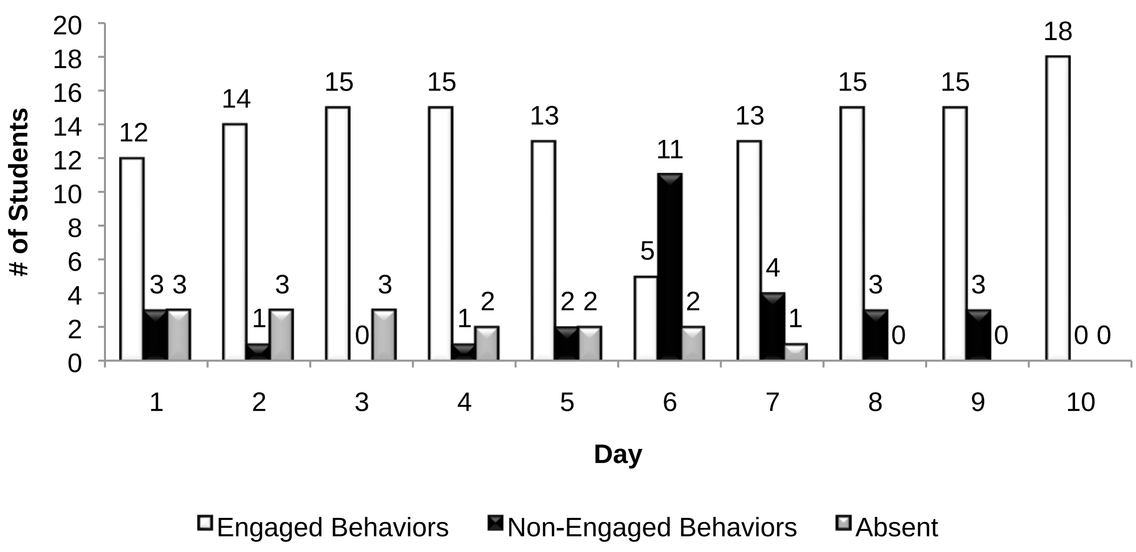

Figure 8. Qualitative field observations for Group 1

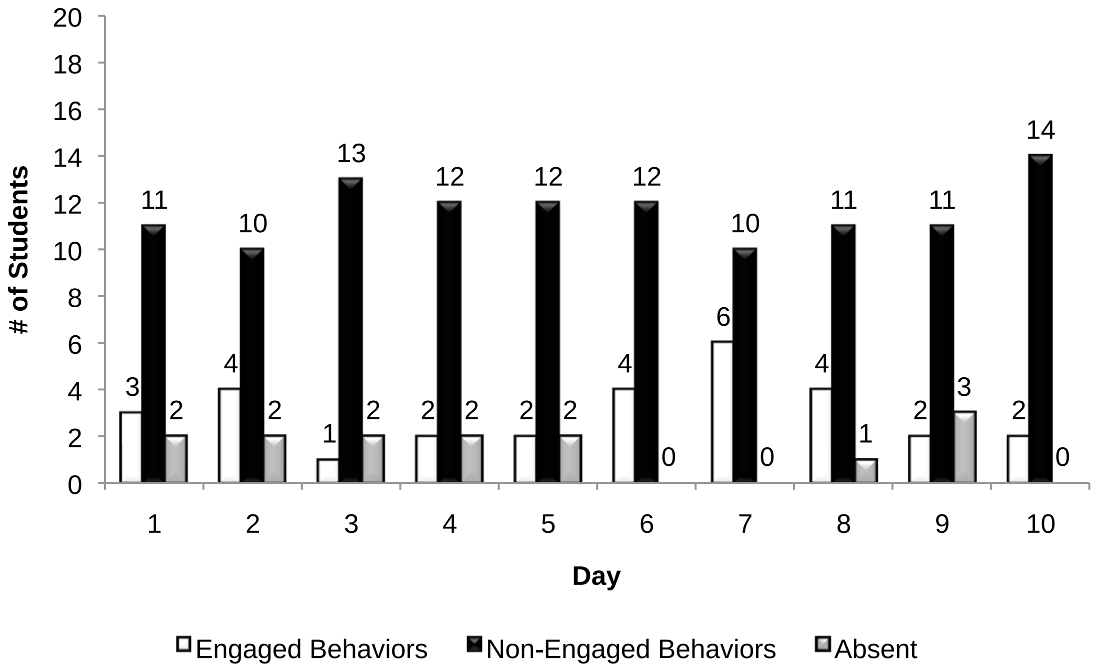

Figure 9. Qualitative field observations for Group 2

CHAPTER 5

ANALYSIS OF RESULTS

Analysis of Pre vs. Post-assessment Results

When comparing average pre vs. post-assessment scores, both groups displayed an increase in content knowledge. Based on pre-assessment data alone, it was obvious that most students did not have much content knowledge to begin with. Naturally we should see an increase in post-assessment scores. There is not an indication that either group triumphed over the other, nor was there data favoring one type of teaching strategy. Both groups gained knowledge from pre to post-assessment and neither group scored dramatically higher than the other. When comparing groups, the overall conclusion is that neither group benefited nor was disadvantaged by the use of PBL strategies and both groups gained knowledge throughout the course of the unit as seen in Figure 4.

That being said, however, it is worth noting that Group 2 started out with a lower average on the pre-assessment (52.5% as compared to 57.8%). This difference of 5.3% indicates that Group 2 had more knowledge to "cover" in the same span of time. When finished, Group 2 actually scored higher than Group 1, on average. Group 2 ended with an average of 83.4% on the post-assessment, Group 1 an 82.9%. This may be an indication that Group 2 may have learned more over the course of the unit, simply due to their starting place. This observation might be contributing evidence that direct instruction, not PBL, allows students to gain more content knowledge. Looking at this data, one could argue that Group 2 gained more content knowledge than Group 1. While this is true, referring back to Figure 4, the scores are very comparable. This data, however, prompted the need for a statistical analysis of the two groups to determine if the difference in numbers is significant.

Statistical Analysis

A mixed between-within subjects analysis of variance (ANOVA) was conducted to determine whether the difference between groups' pre and post-assessment scores had any statistical significance (Hinkle, Wiersma, & Jurs, 2003). As seen in Table 3, there is not a statistical significant difference between the two groups' scores in terms of gained content knowledge. Table 3 shows means of two groups and standard deviation:

TABLE 3

DESCRIPTIVE STATISTICS FOR GROUPS 1 AND 2

	Group	Mean	Std. Deviation	N
Pre	1	52.50	14.259	16
	2	57.78	11.533	18
	Total	**55.29**	**12.965**	**34**
Post	1	83.38	8.617	16
	2	82.89	12.602	18
	Total	**83.12**	**10.753**	**34**

Statistical analyses did not indicate any significant difference between the two groups' performance on pre/post comparisons. However, Group 1 did not score significantly lower than Group 2, which indicates trying new strategies does not inhibit student learning.

Analysis of Learning Gain Scores

The trend seen with learning gain scores is that the majority of the students gained some content knowledge as we progressed through the unit. Another piece of evidence is that students did not drastically benefit from the PBL strategies, nor were they harmed because of them. The majority of the students ended up with a positive gain score, indicating they did actually increase their knowledge regardless of which strategy they were exposed to.

Group 1 LGSs

Individual LGS for Group 1 appear to fall in to 3 categories: low, average and high. By this researcher's standards, "low" is defined as any LGS -.30 and up to .45. "Average" is defined as a LGS of .46 - .70 and "high' is any LGS above .70. Table 4 shows the number of students in each category.

TABLE 4

LGS FOR GROUP 1

LGS Category	LGS Range	# of Students	% of Students
Low	-.30 - .45	5	28%
Average	.46 - .70	7	39%
High	.71 – 1.00	6	33%
Total		**18**	**100%**

On average, Group 1 had a LGS of 0.472 of all possible points. In terms of proving this hypothesis these results are disappointing. It is a positive result to see that most students gained knowledge, especially the three who had a LGS of .95, but there is not a dramatic any lead over Group 2.

Despite the positive trend, two students in Group 1 had a negative LGS. It is the inference of this researcher that those two students simply did not gain any content knowledge for the entire unit. One student, Student 4, would rather talk about cheerleading and boys than concentrate on science. Her attitude in class is never positive and she received the lowest LGS out of all the students in this research study. This indicates to the teacher, that she didn't care to begin with and refused to increase her knowledge as the unit progressed. The other student, Student 9, has had several health issues and has consistently missed weeks of school at a time. She is now in the process of trying to catch up so it is not surprising that her scores are low. She has missed several critical concepts throughout the semester, which may also be a contributing factor. These two simply did not gain any measurable knowledge during this unit, and that is unfortunate. What is more worrisome is the possibility that not only did these two students not gain any knowledge, but that they actually *lost* knowledge from the pre to post-assessment. This teacher would make the assertion that they did not lose knowledge, but rather got lucky on the pre-assessment and their scores were artificially inflated to begin with. Next time, the instructor would intervene more readily. Although this is against one of the foundational premises of PBL, but it cannot be justified to sit back and let the students fail simply to follow procedure. Possibilities of intervention could be a daily quiz to assess content knowledge, students who score low on the pre-assessment could be required to complete a daily checklist or an additional daily assignment. It appears that these two students would not learn the information unless they were physically required to produce something (a quiz or daily assignment) in order to ensure they are working toward gaining, or at the very least maintaining, content knowledge.

Despite those two disappointments, the individual LGS do show a positive result for Group 1. Using Table 4, it can be calculated that 72% of the students in Group 1 (“average” and “high” categories combined) displayed an increase in their LGS. That allows for the inference that most students in Group 1 gained knowledge as the unit progressed which equates to an increase in knowledge from pre to post-assessment.

<u>Group 2 LGSs</u>

The first pattern observed when comparing Figures 5 and 6, is the Group 2 appears to have gained more knowledge due to the fact that individual LGS are higher for Group 2. If the same categories are used as above, Table 5 shows Group 2 displays a smaller percentage of students in the “low” category, with none in the negative range, and a larger percentage of students in the “average” and “high” categories, 81% in Group 2 as opposed to 72% in Group 1. Although the number of students in each of those categories is the same for both classes, the percentage is greater in Group 2 because it is a smaller class. However, the overall difference in these scores is not great enough to indicate that direct instruction is a better way to teach than PBL.

TABLE 5

LGS FOR GROUP 2

LGS Category	LGS Range	# of Students	% of Students
Low	-.30 - .45	3	19%
Average	.46 - .70	7	44%
High	.71 – 1.00	6	37%
Total		**16**	**100%**

Analysis of LGS for Both Groups

The conclusion here is Group 2 had an average LGS of 0.482, and was higher than Group 1. This data does not support the claim that PBL is an effective strategy in terms of gaining content knowledge. Although better results had been anticipated, this data suggests that PBL may not be the best method to use if gaining content knowledge is the priority. Another possibility for the lower LGS is that PBL is difficult to assess. It is possible that students may have had higher LGS if the assessment had been in the same style, format, etc of the PBL scenarios. Overall, the trend is positive and that is a good thing, but it was unfortunate to disprove this part of the hypothesis.

It is also important to consider that both groups did have the benefit of direct instruction for the essentials in the curriculum regarding volcanoes and volcanic eruptions. The post-assessment was designed specifically to assess basic content knowledge and covered more material from the lecture portion of the class than the PBL scenarios. Since both groups had essentially the same instruction at the beginning of the unit, the scores should be comparable. However, a possible modification to the post-assessment could require students to use their basic knowledge in combination with problem solving skills to answer “scenario” type questions. That type of assessment might give a better indication if the PBL strategies are worth using in the classroom.

On the whole, of the 34 students that were studied (Group 1 plus Group 2), 26 students fell in to the “average” or “high” category. Meaning, 26 of them had a LGS of .46 or greater. Table 6 displays again the LGS categories and combines both groups. The “big idea” here is that 76% of all students scored in the “average” or “high” categories and have increased their knowledge. It is also noteworthy again that one strategy did not prevail over the other.

TABLE 6

LGS FOR TOP 26 STUDENTS FROM BOTH GROUPS

LGS Category	LGS Range	# of Students	% of Students
Low	-.30 - .45	8	24%
Average	.46 - .70	14	41%
High	.71 – 1.00	12	35%
Total		34	100%

Analysis of Qualitative Field Notes Results

Looking at Figure 8, it is quite clear that Group 1 showed regular levels of engagement throughout the process. If one were to look closely at the non-engaged behaviors, it could be concluded that these behaviors are relatively low and remain low until Day 6. At that point, numbers peak. This researcher infers this peak is due to the fact that Day 6 was a Monday, and Mondays are difficult days for high school students to focus since they must recover from their strenuous weekend activities. The peak may be due to the fact that this is the beginning of the second week of this project and interest level had waned. At this point, the teacher intervened and gave them the "this is a major part of your grade so get it together" speech and from there attitudes improved. After Day 6, non-engaged behaviors decreased and finally trailed off to zero. The reality that the deadline was approaching and the students had to finish everything in order to be ready to present may have increased engagement behaviors. The "engaged" behaviors were observed in 67% (12 out of 18 students) or more of the student population for nine of the ten days. One of the best things observed about PBL is that it forces students to become engaged. Once the discussion starts, students are literally sucked in to the "what if's". This observation is supported by the fact that on most days students in Group 1 were observed to be engaged in the PBL process.

One case study worth pointing out is the change observed in Student 9 from Group 1. Traditionally this student had missed a lot of school and her attitude had worsened as well as her behavior. She also has had issues with failing grades, problems at home and conflicts with other students at school. After missing 6 consecutive weeks of school, BHS Administration informed her that unless she returned to school immediately, she would be expelled. Hence, she returned. When the 10-day project began, Student 9 was exiled to In School Suspension (ISS) in order to get caught up in her classes. It was requested by the instructor that she be allowed to come to class because it is difficult to participate in PBL strategies if one is not present. It was also the intention of the instructor to bring her in from the introduction of the PBL strategies so she would feel like she was part of the class project. The first day, she came to class completely unprepared with a negative attitude. Her body language was defensive, her language was atrocious and her behaviors required the teacher to intervene several times with little change within the first few days of the project. It was the thought of the teacher to perhaps send her back to ISS and exempt her from the entire project. However, as Day 4 approached her engagement level, and in turn, her attitude and behaviors improved. Once the PBL scenarios progressed and students began formulating solutions, the chip on her shoulder disappeared, her participation increased and she began displaying engaged behaviors. By the end of the unit she was a different person. She and her group presented their solutions, dressed beautifully and professionally, with confidence and spouted off facts about their scenario like a true volcanologist. Even though her overall LGS was negative, it is the belief of the teacher that she did gain some knowledge. It may not have been the knowledge needed to score well on the post-assessment, but she learned *something* through this process nonetheless. More importantly, this girl's engagement in school overall increased. She was once failing all seven subjects, and she is now only failing two classes. Plus, she has claimed she is working on getting those grades up. She had been failing science class for all of January and February and part of March with no interest in raising her grade. She went from a 33% in this science class to a 90%. It is not the claim of this researcher that PBL solved all her problems, but it gave her the opportunity to become engaged in something other than the "you're failing!" mantra she heard every day upon returning to school. PBL has been linked to the conclusion that "instructional materials that are challenging, give students choices, and promote perceived autonomy and self-determination can have a positive effect on students' motivation" (Deci & Ryan, 1985; Hidi & Harackiewicz, 2000). These types of case studies might be worth researching on an individual basis to endorse PBL strategies and the claim that there is an increase in motivation when using them in the classroom.

On another positive note, students in the PBL group expressed they liked having a choice in their projects and that it seemed "more real" than just taking notes. Students also liked using technology such as the laptop computers and iPods. Several students claimed they learned a lot about the technology they were creating their projects in (ex. PowerPoint, Comic Life, Excel, etc) just by using it. Students also enjoyed seeing their projects displayed online. The teacher created a Weebly page for the projects and posted them online for everyone to see.

The engagement portion of the original hypothesis was proven correct. Based on observations and conversations in the classroom, students are more engaged when they are part of a PBL scenario. Figures 8 and 9 indicate that students were consistently more engaged when solving a problem. Reasons for this include PBL seems more interesting to students, students like to stand up and move around the classroom, therefore displaying more engaged behaviors. Direct instruction leaves little room for students to display engaged behaviors, and it is possible some students were engaged, but this researcher did not recognize their behavior. Group 2 consistently shows lower interest in the class, as a whole, than Group 1. In light of this information, the researcher decided to analyze the on-task vs. off-task behaviors displayed in the two groups. Based on qualitative observations, Group 2 can be described as "on task, but not engaged". Group 1 is described as "on-task and engaged". "On-task" being defined as students completing assigned work, taking notes and/or creating a poster. So, students can complete a task they are given without displaying behaviors that would consider them to be "engaged". However, they were not displaying inappropriate behavior either. Many students in Group 2 simply finished their work quietly, never asking questions nor socializing with each other. This class is a constant source of frustration because most of them simply do not care enough to become engaged. They complete what they are asked to do, with little to no complaint, and blend into the walls for the rest of the class period. It is very difficult to get them to participate in a discussion, or even answer questions. Upon reflecting on the class dynamics, *this* class may have been better served as the experimental group to investigate if PBL strategies would excite them.

However, because Group 2 displayed these behaviors, it made way for the opportunity to infer that students can be on-task and do what they are told, without being engaged in the learning process. USD 313 Assistant Superintendent, Dayna Richardson, always says, "They can be busy, but are the *engaged*?". In this case, Group 2 is being productive, but there is no engagement in the learning process as shown in Figure 10. Based on this qualitative data, it can be stated that in terms of engagement, PBL is more effective than direct instruction.

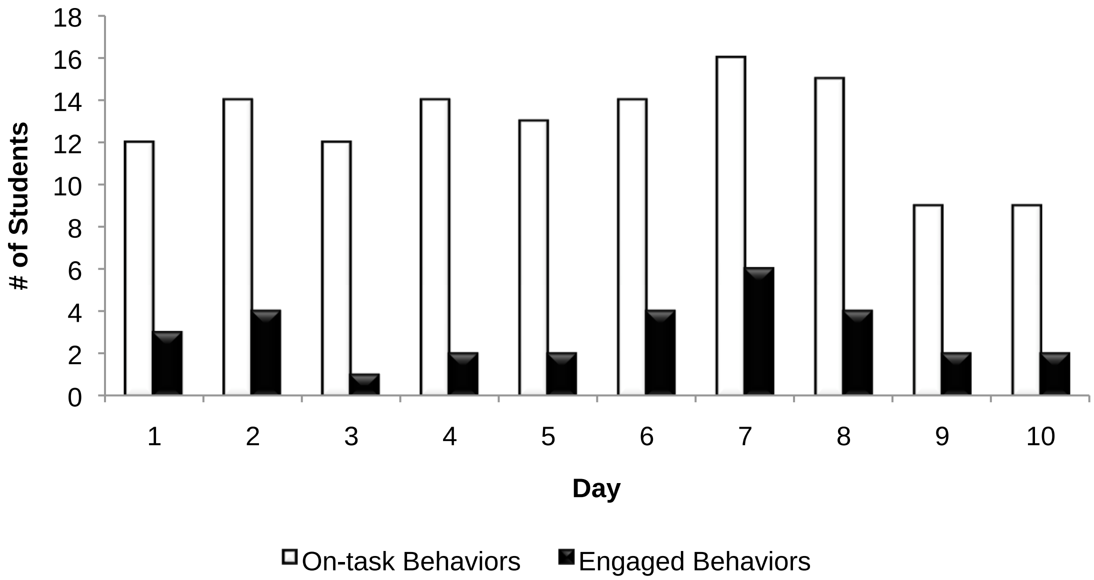

Figure 10. On-task vs. engaged behaviors for Group 2

CHAPTER 6

CONCLUSIONS

After careful analysis of all available data, this study concludes that PBL is effective in the science classroom in terms of increasing student engagement, but does not have a major effect, one way or the other, on increasing student content knowledge. The hypothesis of this research project states that the students who participated in the PBL strategies would gain more content knowledge and be more engaged than the control group. This assumption would then lend itself to the conclusion that the students learn more effectively when given a problem to solve and are allowed to make some choices in their learning. Based on the results of the pilot study, PBL must be coupled with some varied teaching methods, such as direct instruction, in order for students to be successful. Research indicates that these claim are true. After identifying these limitations, Akinoglu & Ozkardes Tandogan (2007) designed a study that used PBL learning to teach Forces of Motion to a research group and then subsequently taught the same topic to a control group (p. 76). After the strategies were complete, academic achievement was compared. There was no significant gain in knowledge between the two groups, however, it was "observed that there is a positive change in the attitudes of the research group students towards science class" (Akinoglu & Ozkardes Tandogan, 2007, p. 77).

Several factors have been considered to come to the conclusion that the original hypothesis should be considered partially true and subject to further revisions.

A Usable Strategy for High School Classrooms

PBL is not going anywhere. In order to make this strategy usable in a high school science classroom, it needs to be introduced early in the year and offer an enticing scenario that peaks student interest. It is this researcher experience that proper credit be given to the value of direct instruction as well.

In their research study, Gurses et al. said this about direct instruction versus PBL strategies:

> Lecturing is still efficient and has persisted as the traditional teaching method largely because it is familiar, easy, and how we learned (Duch et al., 2001). However, PBL can be preferred especially in laboratory courses because it fosters the development of process skills (Duch et al., 2001).

This study has proven that PBL and direct instruction, combined with appropriate intervention measures, insure both engagement in the learning process and an accumulation of content knowledge. Once the guidelines of PBL are firmly established, the instructor can pick multiple PBL scenarios and present them throughout the year, hopefully engaging students to problem solve in a variety of situations.

Another question to consider would be to determine what order to use PBL and other best-practice strategies. Is it better to instruct first to give them basic, foundational knowledge or to present the PBL scenarios and allow *them* to decide what knowledge is essential and what is supplemental? There is a place for learning centers, direct instruction, PBL and a plethora of other strategies in the 9-month long school year. It is important that an instructor realize when to use PBL and when techniques like direct instruction may be better suited. It is a classic argument that presented itself at my previous job in education as well. Do you let the students have the experience first, maybe fumble a little bit, and then do the direct instruction? Or is it better to do it the other way around? This is a question that may never be answered, but it surely one that any teacher should contemplate when deciding on the best approach to use in his/her classroom. There are times in a classroom when PBL is the best way to engage students in a lesson and there are other times when an effective instructor must realize that PBL is not going to give the students the knowledge they need. Any strategy, PBL or not, "should enhance and promote the goal of a course, not serve as a digression in curriculum and pedagogy. The problem should promote students' knowledge and skills that have been defined as intended course outcomes" (Gurses et al., p. 103-104).

There is a huge push in education for PBL to become the rule rather than the exception. It is the belief of this researcher that PBL needs to be incorporated somehow into the science classroom on at least a quarterly basis. Massa (2008) said it best, "PBL is not another educational fad. It has been tried and tested, and it makes sense. If education institutions are to produce graduates capable of solving real-world problems, PBL is a no-brainer" (p. 20). Then students will have the skills necessary to "work the problem", just as Apollo 13 Mission Controllers did, whatever it may be.

Student Reflections on PBL

PBL is often associated with an increase in student engagement and an excitement about the subject matter (Akinoglu & Ozkardes-Tandogan, 2007). It was observed in this researcher's classroom that students come out of the lessons more confident and interested when using PBL. In order to consider what the actual students were thinking, they were asked to fill out a survey, adopted from the Attitudes in Science Survey (www.ncrrsepa.org/Files/Eval/HSResearch/PostTeacherSurvey.pdf). In this survey, students were asked to reflect on their attitudes about science in general and specifically about their experience with PBL. In the survey, the majority if the students agreed when asked if they preferred hands-on activities, solving problems and working in groups to the traditional lecture-style classroom. This indicates to this researcher that students at the very least enjoy working on these types of problems. Students also indicated that the skills they are learning today will help them in the future and they feel challenged by the current curriculum. See Appendix G for the full results of the student survey.

The students were also asked to reflect on the process of PBL as the presentations came to a close. They were asked to evaluate another group's presentation, evaluate themselves, and evaluate their group members. On the whole all of these evaluations were positive, with the exception of the rare "my group member didn't do anything" complaint. When asked if they enjoyed the process 100% of them said yes. See Appendix H for the full evaluation rubrics.

Teacher Reflection on PBL

Serving as the "guide" or "coach" in this process was difficult for this researcher to get used to. This researcher agrees with all the limitations of PBL as described in Akinoglu & Ozkardes Tandogan (2007) research, specifically the adjustment of the teacher's role. The instructor found it difficult to change teaching styles and not be a source for knowledge for the students, but serve only as a guide through their research. Students were uncomfortable with the idea that they had to learn the material on their own without any supplemental instruction from the teacher and were anxious about how that would affect their grades. In order to be a more effective guide, this teacher is considering attending a workshop or a series of professional development classes may provide the needed support and guidance. There are two notable institutions that provide opportunities for teachers in the area. The Problem-Based Learning Network offers an entire series on how to teach and design PBL scenarios in the classroom (http://pbln.imsa.edu/pd/introinstitutes/index.html). Another source could be the Problem-Based Learning Initiative that also holds workshops in the summer for educators interested in refining the use of PBL in the classroom (http://www.pbli.org/workshops/index.htm). This instructor feels it would be of great benefit to attend some of these workshops, as most of the information used in the classroom for this experiment was gleaned from research and available Internet documents, yet none of it was hands-on. The best way to learn to teach PBL strategies may be to experience PBL directly. As teachers, it is often forgotten that we must always be students. So far, the only exposure to this model of teaching has been passive, it makes sense that in order to get the students to "buy in" to the PBL scenarios, educators as well must experience the curriculum and truly understand the PBL template. Figure 11 shows the template used in the Design Institutes from the Problem-Based Learning Network. This educator believes these institutes would be a helpful addition to this research. Support for this claim comes from James Pellegrino (2006) saying "given that teaching requires a unique form of expertise above and beyond knowledge of a given discipline, we must develop teachers who themselves have adaptive expertise in the domain of daily classroom instruction" (pp. 1-2).

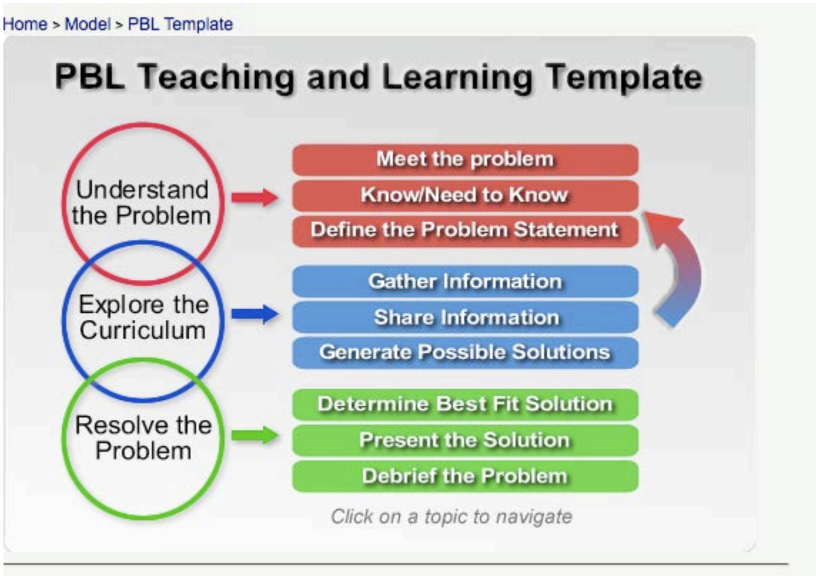

Figure 11. PBL template

<u>Future questions</u>

Research on PBL will no doubt continue in to the future. This area is the push for all, not just science, education. This area of research can be expanded beyond the scope of a high school science classroom and some questions worth researching are:

- Is PBL a strategy that is better served for older students?
- What other teaching strategies are well suited with PBL?
- If PBL was used for an entire semester, would students gain more knowledge?
- How else could PBL be used in higher education?
- Should all teachers be required to be trained in PBL?
- How does PBL affect standardized test results?
- Would case studies following students from elementary to secondary to higher education be appropriate?
- How often should teachers use PBL strategies in their classrooms?

- What is the role of the student and how can teachers prepare them for that role?
- Will PBL ever become obsolete?
- Could PBL be used more in initial teacher education?

Impact of PBL

There is always more than one way to approach a problem and certainly multiple ways to solve a problem. The engineers and scientists who made it possible for the three Apollo 13 astronauts to return safely to Earth did not have pre-fabricated procedures or the Internet at their disposal. The main reason Apollo 13 was not a complete disaster is due to the problem solving skills of NASA's best and brightest minds. It was a series of continual trial and error, with the hope that success would triumph over failure and that their troubleshooting was enough. Somehow NASA employees managed to beat all the odds and keep three men alive as they traveled around the Moon, 250,000 miles away from the nearest "help desk". This didn't happen by shear luck. The ingredients of stellar problem solving skills, determination, and dedication came together in NASA's finest hour.

Students in today's classroom are faced with enormous challenges in the 21st century. They may not realize it yet, but their generation will have to find a way to *solve*, not just discuss, the problems that are arising today. Each generation will have that moment when they realize "we have a problem" and it is how they choose to respond to those problems that will define their generation. From the energy crisis to global warming to the search for extraterrestrial life, and many, many others, students are faced with a multitude of challenges that are coupled to the hi-tech information age. Students today are asked to complete tasks and learn material that was unheard of 30 years ago. It is the responsibility of all educators to instill a sense of purpose and provide them with the skills and confidence to go forth to solve the world's problems. PBL is one-way educators can help students become competent problem solvers and face those challenges head on. "The North Central Regional Educational Laboratory and the Metiri Group identified learning skills essential for students to thrive in the 21st century and developed criteria to gauge progress in those skills" (North Central Regional Educational Laboratory and the Metiri Group). Figure 12 lists those skills, all of which are fundamental to the philosophy behind PBL.

Digital-Age Literacies	Inventive Thinking
• Basic Literacy • Scientific Literacy • Economic Literacy • Technological Literacy • Visual Literacy • Information Literacy • Multicultural Literacy • Global Awareness	• Adaptability/Managing Complexity • Self-Direction • Curiosity • Creativity • Risk-taking • Higher-Order Thinking and Reasoning
Effective Communication	**High Productivity**
• Teaming and Collaboration • Interpersonal Skills • Personal Responsibility • Social and Civic Responsibility • Interactive Communication	• Prioritizing, Planning and Managing for Results • Effective Use of Real-World Tools • Ability to Produce Relevant, High-Quality Products

Figure 12. 21st Century skills needed

There may never be a time in our students' lives when they must save the lives of astronauts on the dark side of the Moon, but there will certainly be a time when their problem-solving skills will be put to the test. "Even if the students never encounter the situation they are investigating, attitudes and engagement seem to have a positive correlation when strategies like problem-based learning are used" (Akinoglu & Ozkardes-Tandogan, 2007, p. 77). PBL "requires authenticity. PBL engages student learning in ways that are similar to real world situations and assesses learning in ways that demonstrate understanding and not mere replication" (Torp & Sage, 2002). It is our job as educators to fine-tune their skills so they are able to attack and solve those problems, and PBL does just that. Students who are exposed to inquiry-based methods like PBL are able to "use the habits of mind and knowledge of science, mathematics, and technology they have acquired to think about and make sense of many of the ideas, claims, and events that they encounter in everyday life (American Association for the Advancement of Science, 1993). With 21st century skills and PBL, students should be able to answer any distress call with, "Houston, we have the problem solved".

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APPENDICIES

APPENDIX A

PRE-ASSESSMENT

1. A theory that helps to explain the causes of both earthquakes and volcanoes is the theory of [continental drift or plate tectonics]

2. Where are volcanoes most likely to form?
    a. a. near the center of continents c. along plate boundaries
    b. b. in deep canyons d. in mountainous areas

3. Volcanic activity is common along the Mid-Atlantic Ridge. This activity occurs at a [convergent boundary, subducted plate, or divergent boundary]

4. Lava that is very runny probably
    a. a. has a low silica content c. has been cooled below the surface
    b. b. is hotter than most lava d. comes from explosive volcanoes

5. Magma that has a high silica content
    a. a. has a thin, runny consistency c. has a thick, runny consistency
    b. b. has a high carbon dioxide content d. has a thick, stiff consistency

6. Which of the following is forced to the Earth's surface when a volcano forms? [steam, lava, or magma]

7. An explosive volcanic eruption can give flight to solid rock fragments called [lava flows or pyroclastic material]

8. Silica-rich magma tends to harden in a volcano's vent, often causing
    a. a. non-explosive eruptions c. lava flow
    b. b. explosive eruptions d. earthquakes

9. Pyroclastic material is classified primarily by
    a. a. particle size c. temperature
    b. b. color d. iron content

10. Large amounts of volcanic ash can cause
    a. a. destruction of trees and buildings c. climatic changes
    b. b. flooding d. all of the above

11. When a volcano's magma chamber empties and its roof collapses, it forms a
    a. a. cavity c. crater
    b. b. caldera d. coprolite

12. Layers of lava from non-explosive eruptions build up to form a
    a. a. caldera c. composite volcano
    b. b. shield volcano d. volcanic block

13. Pressure from the rock above keeps the rock in the Earth's mantle in a
    a. a. gaseous state c. liquid state
    b. b. solid state d. border state

14. Nearly 75 percent of the world's active volcanoes on land are found along a circuit of tectonic plate boundaries known as
    a. the Circle of Gold
    b. the Bermuda Triangle
    c. Volcano Alley
    d. the Ring of Fire

15. Magma rises toward the surface of the Earth because it is
    a. a. denser than the surrounding rock
    b. b. full of air bubbles
    c. less dense than the surrounding rock
    d. the same density as the surrounding rock

16. A volcano can form at
    a. a. a divergent boundary
    b. b. a convergent boundary
    c. neither of the above
    d. both of the above

17. Hot spots are directly below [volcanic islands or mantle plumes]

18. Which lava erupts underwater, forming rounded lumps? [pahoehoe or aa lava]

19. Most of the lava on the Earth's continents erupts from long cracks in the Earth's crust called [fissures or crevasses]

20. As you move away from the hot spot under the Hawaiian Islands, the age of the islands increases. The older islands are farther away of the newer islands because they
    a. aged faster than those to the east
    b. formed first and then were transported away from the hot spot
    c. were made of less lava than the southeastern islands
    d. formed from old, recycled, silica-rich magmas

APPENDIX B

FORMATIVE QUIZ

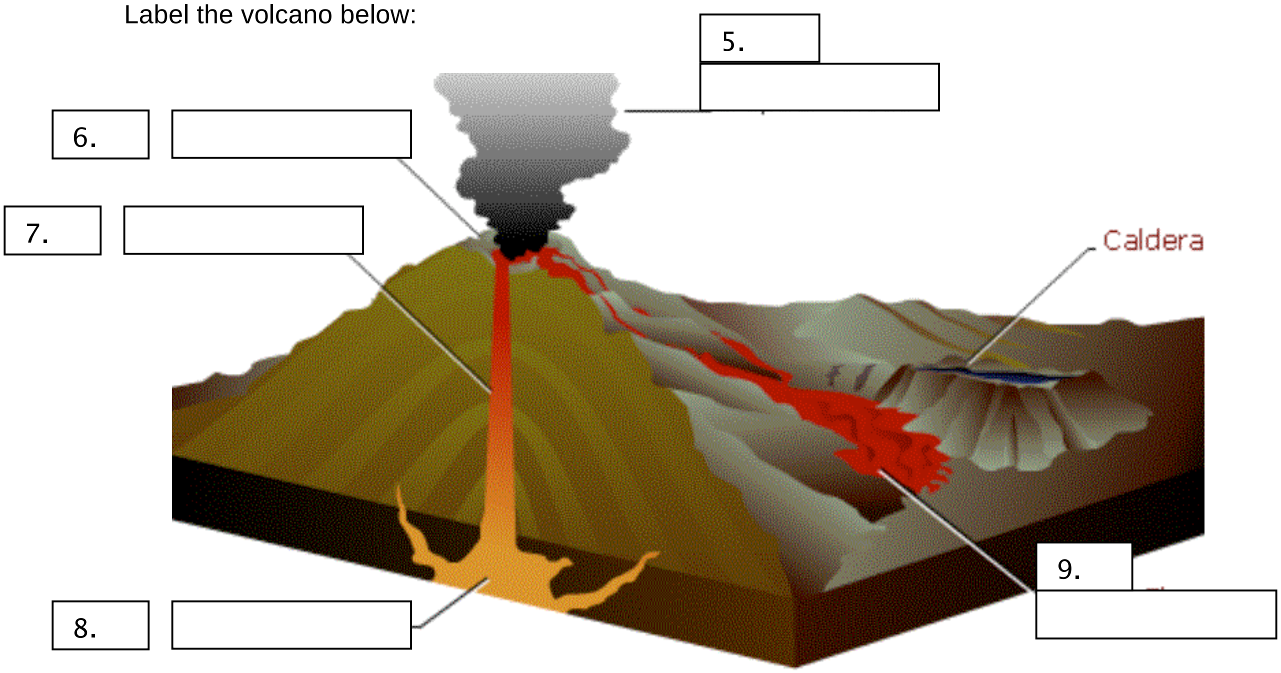
1. If a volcano has explosive eruptions, what can be said about its magma content?
   a. it has a low silica content
   b. it has a high silica content
   c. it will be runny and flow freely
   d. there are not a lot of gases built up in the magma
2. What would typically see you see at the Hawaiian Islands?
   a. Aa and Pahoehoe lava
   b. highly viscous lava
   c. pyroclastic flows
   d. Pahoehoe lava, but no aa lava
3. Define the following:

   <u>composite volcano</u>: (high/low) viscosity lava, (violent/quiet) eruptions
   <u>cinder cone volcano</u>: (high/low) viscosity lava, (violent/quiet) eruptions
   <u>shield volcano</u>: (high/low) viscosity lava, (violent/quiet) eruptions

4. In 1980, Mt. St. Helen's made history with its explosive eruption that triggered lava and pyroclastic flows. What type of volcano is Mt. St. Helen's?

   a. Super Volcano
   b. Fissure Volcano
   c. Shield Volcano
   d. Composite Volcano

Label the volcano below:



10. Define viscosity.

11. What flows more easily, a highly viscous fluid, or a fluid with a low viscosity?

12. If the volcanoes magma is highly viscous, then the eruption will be (violent/non-violent).

13. If the volcanoes magma has low viscosity, then the eruption will be (violent/non-violent).

14. Why are volcanoes with high viscosity so explosive?

15. Why are low viscous magmas associated with quiet eruptions?

16. List 2 other factors may affect the viscosity of a magma.

Match the type of magma with the correct volcano

17.	__________	Shield	a. Andesitic
18.	__________	Cinder Cone	b. Rhyolitic
19.	__________	Composite	c. Basaltic

20. List 3 signs that a volcano is about to erupt.
    1.
    2.
    3.

APPENDIX C

POST-ASSESSMENT

Multiple Choice
Identify the choice that best completes the statement or answers the question.

1. A magma's viscosity is directly related to its ____.

a. depth	c. color
b. age	d. silica content

2. Which of the following factors helps determine whether a volcanic eruption will be violent or relatively quiet?

a. amount of dissolved gases in the magma
b. temperature of the magma
c. composition of the magma
d. all of the above

3. A lava flow with a surface of rough, jagged blocks and sharp, angular projections is called a(n)

a. pyroclastic flow	c. pahoehoe flow
b. aa flow	d. ash flow

4. As the temperature of lava increases, ____.

a. its viscosity decreases	c. its viscosity increases
b. it begins to harden	d. it can flow a much shorter distance

5. Which list places the magma types in order of decreasing viscosity (most viscous listed first)?

a. basaltic, andesitic, rhyolitic	c. andesitic, basaltic, rhyolitic
b. rhyolitic, andesitic, basaltic	d. basaltic, rhyolitic, andesitic

6. Highly explosive volcanoes tend to have what type of magma?

a. magma with high silica, high viscosity, and higher gas content
b. magma with low silica, low viscosity, and lower gas content
c. magma with low silica, high viscosity, and lower gas content
d. magma with no silica, high viscosity, and no gas content

7. The broad, slightly dome-shaped volcanoes of Hawaii are ____.

a. composite cone volcanoes	c. pyroclastic volcanoes
b. shield volcanoes	d. cinder cone volcanoes

8. A volcano that is fairly symmetrical and has both layers of lava and pyroclastic deposits is a ____.

a. cinder cone volcano	c. pyroclastic volcano
b. shield volcano	d. composite volcano

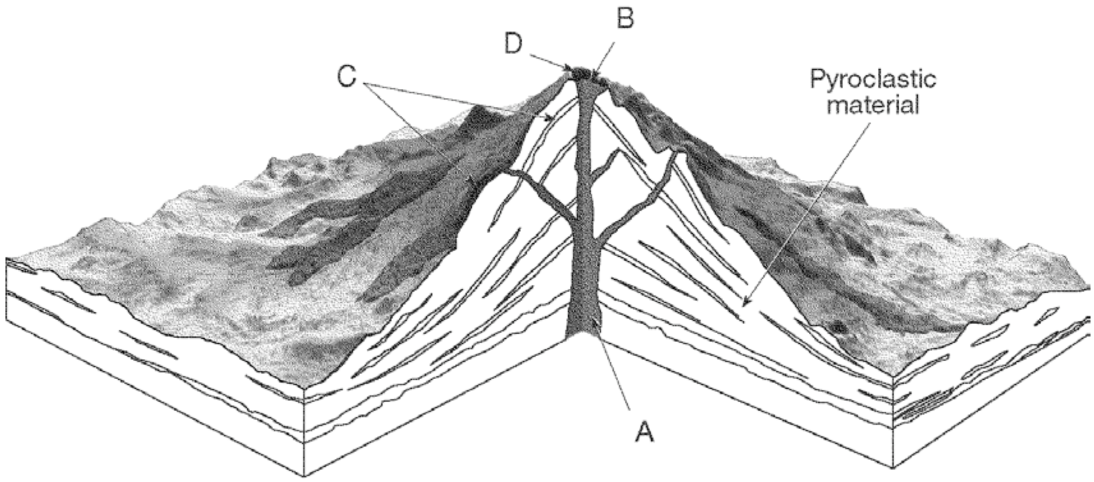


Figure 10-1

9. What feature is labeled C in Figure 10-1?
a. pipe
b. volcanic neck
c. lava flows
d. eruption cloud

10. What feature is labeled A in Figure 10-1?
a. pipe
b. volcanic neck
c. crater
d. vent

11. What type of volcano is illustrated in Figure 10-1?
a. volcanic neck
b. shield volcano
c. cinder cone
d. composite

12. Which of the following plays a major part in determining the form of a volcano?
a. elevation above sea level
b. local soil type
c. magma composition
d. nearness of other volcanoes

13. Which of the following is true about cinder cones?
a. They have gently sloping sides
b. They are usually less than 300 meters high.
c. They are the most common in the world
d. all of the above

14. The most violent volcanic eruptions are associated with what type of volcano?
a. cinder cones
b. shield volcanoes
c. composite volcanoes
d. fissure eruptions

15. Magma forms when solid rock in the crust and upper mantle ____.
a. melts
b. vaporizes
c. crystallizes
d. cools

16. Magma tends to rise towards Earth's surface primarily because ____.
a. water is abundant in magma
b. rocks become less dense when they melt
c. silica is abundant in magma
d. rocks become more dense when they melt

17. The volcanic landforms at divergent ocean plate boundaries are ____.
a. oceanic ridges
b. volcanic island arcs
c. continental volcanic arcs
d. ocean trenches

18. Most of the active volcanoes on Earth are located in a belt known as the ____.
a. circum-Atlantic belt
b. Ring of Fire
c. Mid-Atlantic Ridge
d. East African Rift Valley

19. Which type of landform develops at plate boundaries where one oceanic plate descends beneath another?
a. rift valley
b. volcanic island arc
c. mountain ranges formed by a batholith
d. lava plateau

20. Which of the following is NOT a factor affecting how explosively or quietly a volcano erupts?
a. magma's composition
b. magma's temperature
c. concentration of dissolved gases in the magma
d. size of the volcano's cone

21. The particles produced in volcanic eruptions are called ____.
a. laccoliths
b. calderas
c. pyroclastic material
d. volcanic stocks

22. Which of the following is NOT considered to be a pyroclastic material?
a. ash
b. lapilli
c. cinders
d. pahoehoe

23. A caldera is a ____.
a. type of volcanic eruption
b. type of volcano
c. large depression in a volcano
d. very large volcanic bomb

24. Lava plateaus form when ____.
a. the top of a volcano collapses
b. fluid basaltic lava flows out of fissures
c. lahars create new landforms
d. pyroclastic flows erupt from volcanoes

25. Most shield volcanoes have grown from the ocean floor to form ____.
a. islands
b. dikes
c. tectonic plates
d. canyons

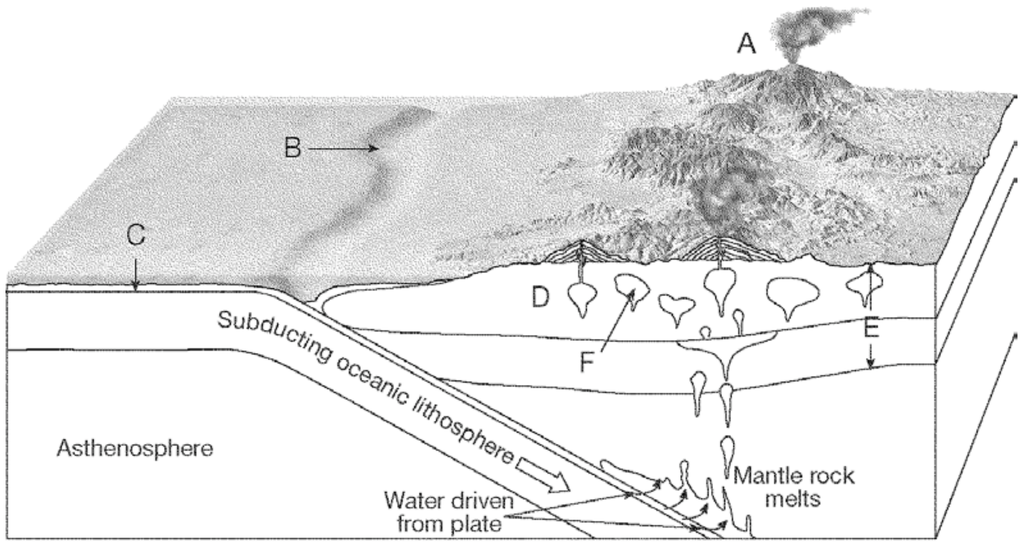


Figure 10-2

26. What volcanic feature is illustrated at A in Figure 10-2?
a. continental volcanic arc
b. volcanic island arc
c. hot spot
d. ocean ridge

27. What type of plate boundary resulted in the volcanic activity illustrated in Figure 10-2?
a. divergent plate boundary
b. oceanic-oceanic convergent plate boundary
c. oceanic-continental convergent plate boundary
d. continental-continental convergent plate boundary

28. The igneous activity in Yellowstone National Park is associated with what tectonic setting?
a. divergent plate boundary
b. convergent oceanic-oceanic plate boundary
c. intraplate setting
d. convergent oceanic-continental plate boundary

29. The Hawaiian Islands are associated with what type of volcanism?
a. intraplate volcanism
b. subduction zone volcanism
c. volcanism at a divergent plate boundary
d. volcanism at a convergent plate boundary

Completion
Complete each statement.

30. A material's ____________________ is a measure of its resistance to flow.

31. The most explosive volcanoes are produced by magma with ____________________ viscosity that contains a large quantity of dissolved gases.

32. Particles of rock, lava, ash, and other volcanic fragments blown from the vent of a volcano are called ____________________.

Matching: The pictures of the volcanoes will be shown to you on the screen. match the type of volcano with the correct name of the volcano. You will need to use some of the answers than once.

a. composite
b. shield
c. supervolcano
d. fissure volcano
e. cinder cone

____ 33. Hawaiian Islands

____ 34. Mid-Atlantic Ridge

____ 35. Yellowstone

____ 36. Mt. St. Helen's

____ 37. Olympus Mons

____ 38. Paracutin, Mexico

____ 39. Krakatoa

____ 40. Iceland

Short Answer

41. What are the three main types of volcanoes?

42. What is the definition of a volcano?

43. List 3 signs that a volcano is about to erupt.

1.

2.

3.

44. List the following characteristics for **Explosive** Eruptions
Plate Setting:
Type of Volcanoes (2 types):
Type of Magma (2 types):

45. List the following characteristics for **Quiet** Eruptions
Plate Setting:
Type of Volcano:
Type of Magma

APPENDIX D

VISCOSITY LAB

Purpose:
The purpose of this activity is to investigate the relationship between viscosity, or the thickness of a liquid, and the speed at which a marble falls through the liquid. This is to give you an idea of how the viscosity of magma affects the explosiveness of a volcanic eruption.

Procedure:

- Each lab station is set up with a different liquid
- At each of the lab stations, drop the marble into the graduated cylinder
- Using a stopwatch, record the length of time it takes the marble to fall from the 100 mL mark to the 20 mL mark.
- Repeat 3 times.
- Move to the next station and repeat procedure.

Data:

	Viscosity	**Time**			
		Trial 1	Trial 2	Trial 3	Average
Maple Syrup	2.5				
Honey	10				
Light Corn Syrup	110				

Analysis:
Make a **LINE GRAPH** of Viscosity (given in the above table) vs. Average Time of Falling

Post-Activity Questions:

1. Define viscosity.

2. What is the relationship between viscosity and the time it takes a marble to fall?

3. What flows more easily, a highly viscous fluid, or a fluid with a low viscosity?

5. What is the relationship between the magma's viscosity and the explosiveness of a volcano?

6. What does this tell us about the shape of volcanoes?

7. Why do you think volcanoes with high viscosity are so explosive? Why are low viscous magmas associated with quiet eruptions?

8. What other factors may affect the viscosity of a magma?

9. What is the best way to test the actual viscosity of magma from a volcano?

10. If you were to test another variable in this experiment, what would it be and why?

APPENDIX E

VOLCANO SITUATIONS PROJECTS CHECKLIST

Directions: Place a check mark when the task is completed. Mrs. Sindelar will come around to your group and give you approval to continue.
Our Situation: ___________________________

Project Checklist:
Items We Must Understand:

____ What the project is

____ When the project is due. Due Date: _______________

____ All 11 requirements

____ How to cite a source and complete research

Items We Must Prepare:

____ Decide what kind of a product you wish to make

____ Begin research for your volcano
(use time wisely, our computer time is very LIMITED)

____ Gather materials (poster board, supplies, markers, rulers, computers, iPods, etc)

____ Decide who is responsible for what parts of the product and the presentation

_______________________ Teacher's Initials/Approval to Proceed

Items We Must Complete:

____ Meet all 11 requirements outlined in your packet

____ Title – give your project an official title

____ Labeling – Volcano Name, Your Names, Hour, etc
(more labeling is better than not enough!)

____ Construction of your product (neatness counts!!)

____ Any extra elements or 3-D effects you wish to use

____ Cite 3 different sources of material

____ Type all written material into Pages

____ Make an outline of who is doing what for your presentation

____ Perform a comprehensive risk analysis using the additional pages on the Volcano situations page.

____ Display your finished project around the room

APPENDIX F

ASSESSMENT PIECES FOR PBL STRATEGIES

Presentation Guidelines

General Requirements:
- TAKE THIS SERIOUSLY!
- It is weighted as much as a test grade – worth mucho points!!
- Must be 5-7 minutes long
- All group members must be dressed professionally
- All group members must actively participate in the presentation
- Groups will be peer grading each other as well as the teacher
- DO NOT just read from a piece of paper!!!

Introduction:
- Attention Grabber - get the attention of the class by saying, doing or demonstrating something exciting
- One person introduces the whole group

The Situation:
- State the problem situation (Requirement #1)
- Describe the known factors (Requirement #2)
- Tell the class what the problem is and what challenges you are faced with (Requirement #3)

The Volcano:
- Give the factual information about your volcano (Requirements #4-8)
- Use visual aids or 3-D models to enhance this part of your presentation (Requirement #9)
- Describe in detail why this volcano poses a risk to your population
- Perform a comprehensive risk analysis using the additional pages on the Volcano Situations page.

The Solution:
- State possible solutions and reasons why you decided against those solutions
- Describe in detail your recommendations (Requirements #10-11)
- Back up your findings with research, mathematical equations (at least 1), and references
- Describe the consequences of your decision

Conclusion:
- Restate your problem statement and solution
- Thank the audience for listening
- Ask for questions
- Answer questions posed by fellow classmates, peer grading group, teacher, or other visitors

Volcano Product Rubric

Names of Group Members:

______________________________ ______________________________

____

General Requirements:

• Presentation met time requirement	Yes (+5)	No (+0)
• All Group Members dressed appropriately	Yes (+5)	No (+0)
• All Group Members participate in the presentation	Yes (+5)	No (+0)

Introduction:

• Attention Grabber – Group gets your attention	5	4	3	2	0
• One person introduces the whole group	5	4	3	2	0

The Situation:

• Group states the problem situation	5	4	3	2	0
• Group describes the known factors	5	4	3	2	0
• Describes what challenges you faced	5	4	3	2	0

The Volcano:

• Gives the factual information about the volcano	5	4	3	2	0
• Uses visual aids or 3-D models	5	4	3	2	0
• Describes why this volcano poses a risk	5	4	3	2	0
• Performs a comprehensive risk analysis	5	4	3	2	0

The Solution:

• States all possible solutions	5	4	3	2	0
• Describes in detail their recommendations	5	4	3	2	0
• Describes the consequences of their decision	5	4	3	2	0

Conclusion:

• Restates their problem and solution	Yes (+5)	No (+0)
• Thank the audience for listening	Yes (+5)	No (+0)
• Ask for questions	Yes (+5)	No (+0)
• Answer questions	Yes (+5)	No (+0)

TOTAL GRADE FOR ENTIRE PROJECT: ______________________

Comments:

Volcano Product Rubric

Student's Name________________________ Hour: ____________

All wording is typed (+4)	**Yes (+4)**			**No (+0)**	
References typed and attached to the poster (+5)	**Yes (+5)**			**No (+0)**	
• At least 3					
Geographic Location of the Volcano (+8)					
• Geographic information	**4**	**3**	**2**	**1**	**0**
• Latitude/longitude	**4**	**3**	**2**	**1**	**0**
Map of the Volcano with a star (+2)	**2**	**1**	**0**		
Type of Volcano (+2)					
• Shield, composite, cinder, hot spot, caldera	**2**	**1**	**0**		
Tectonic setting of the volcano (+2)					
• Convergent, divergent, transform, hot spot	**2**	**1**	**0**		
Characteristics of the Volcano (+12)					
• Landscape	**4**	**3**	**2**	**1**	**0**
• Type of climate	**4**	**3**	**2**	**1**	**0**
• Land formations	**4**	**3**	**2**	**1**	**0**
Biggest Eruption (+24)					
• Date	**4**	**3**	**2**	**1**	**0**
• Climate changes	**4**	**3**	**2**	**1**	**0**
• Distance lava/pyroclastic material flowed	**4**	**3**	**2**	**1**	**0**
• Personal accounts (2)	**4**	**3**	**2**	**1**	**0**
• # of people in area	**4**	**3**	**2**	**1**	**0**
• # of people killed or hurt	**4**	**3**	**2**	**1**	**0**
Pictures (3) of the Volcano (+3)	**Yes (+3)**			**No (+0)**	
Title (+2)	**Yes (+2)**			**No (+0)**	
Your Name on the Poster (+2)	**Yes (+2)**			**No (+0)**	
Neatness (+5)	**Yes (+5)**			**No (+0)**	
Extra elements or 3-D effects					
• 3-D Elements	**10**	**X _______**	**=**	**_________**	
• Extra Information	**5**	**X _______**	**=**	**_________**	
• Extra pictures, maps, diagrams	**5**	**X _______**	**=**	**_________**	

TOTAL:

APPENDIX G

STUDENT ATTITUDES ABOUT SCIENCE SURVEY RESULTS

Question	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
a. I enjoy Science	0	0	2	11	5
b. Science is useful in everyday life	0	0	0	10	8
c. Scientists don't often have good social skills	3	7	6	2	0
d. Doing science often makes me feel nervous or upset	7	8	1	1	1
e. Science challenges my mind	0	0	4	9	5
f. The science instruction that I have received will be helpful for me in the future	0	1	1	10	6
g. Scientists usually work with colleagues as part of a team	0	0	4	7	7
h. I am good at science	1	1	4	10	2
i. Advancements in science and mathematics are large responsible for the standard of living in the US	0	0	4	4	10
j. I usually understand what we are doing in science class	0	1	1	8	8
k. Knowing science really doesn't help a person get a job	5	4	4	2	3
l. Science is difficult for me	4	9	2	2	1
m. Working as a scientist sounds pretty lonely to me	1	8	5	3	1
n. Studying hard in science is not cool to do	10	4	3	1	0
o. Even without a strong background in science, I will probably end up with a kind of job that I want	2	4	3	6	3
p. Overall, science and mathematics have caused more good than harm in our lives	1	0	1	9	7
q. I will probably take more advanced science courses available to me at this school.	4	5	5	3	1

APPENDIX H

STUDENT REFLECTION RUBRICS

Volcano Situations Group Evaluation

Directions: Honestly evaluate the performance and contributions of your other group members throughout this project. Give credit where credit is due, but don't pat anyone on the back if they don't deserve it**. All information will be kept confidential.**

1. I feel like each group member contributed equally to the project **Yes** **No**

   If someone did not, list his or her name(s) here ___________________________________

2. My group got along well **5** **4** **3** **2** **0**
3. My group used our time wisely **5** **4** **3** **2** **0**
4. Do you think the project came together well? **5** **4** **3** **2** **0**
5. Do you think your presentation went well? **5** **4** **3** **2** **0**
6. If you could have chosen, would you have picked your current group members? **Yes** **No**
7. Below list the group member's name, their agreed-upon responsibilities and what grade you would give them

Names of Group Members:	**Their Responsibilities**	**Grade**
______________________________	____	_____
______________________________	____	_____
______________________________	____	_____

Volcano Situations Self Evaluation

Directions: Honestly evaluate your performance and contributions to the group throughout this project. Give credit where credit is due, but don't pat yourself on the back if you don't deserve it.

1. I feel like I contributed to the project **5** **4** **3** **2** **0**
2. I used my time wisely during class **5** **4** **3** **2** **0**
3. I worked on this project outside of class **5** **4** **3** **2** **0**
4. I had good ideas and shared them with my group **5** **4** **3** **2** **0**
5. Do you think the project came together well? **5** **4** **3** **2** **0**
6. Do you think your presentation went well? **5** **4** **3** **2** **0**
7. Is there anything you would change if you were to do it all over again? **Yes** **No**

   If yes, what would you change? ____

8. What was the worst part about this project?
9. What was your favorite part about this project?
10. What grade do you think you deserve for this entire project?