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Problem-based Learning in the Middle School Science Classroom

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Abstract

In 1995, US 12th graders performed below the international average for 21 countries on a test of general knowledge in mathematics and science. (National Center for Education Statistics (NCES), 1998). In 2000, 93% of students in grades '5-9 were taught physical science by a teacher lacking a major or certification in the physical sciences (National Center for Education Statistics, 2002). U.S. 15-year-olds ranked 24th out of 40 countries that participated in a 2003 administration of the Program for International Student assessment (PISA) examination, which assessed students' ability to apply mathematical concepts to real world problems (National Center for Education Statistics, 2005).

Problem-based Learning in the Middle School Science Classroom

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Problem-Based Learning in a Middle School Science Classroom

Chapter One

Introduction

In 1995, US 12th graders performed below the international average for 21 countries on a test of general knowledge in mathematics and science. (National Center for Education Statistics (NCES), 1998). In 2000, 93% of students in grades 5-9 were taught physical science by a teacher lacking a major or certification in the physical sciences (National Center for Education Statistics, 2002). U.S. 15-year-olds ranked 24th out of 40 countries that participated in a 2003 administration of the Program for International Student assessment (PISA) examination, which assessed students' ability to apply mathematical concepts to real world problems (National Center for Education Statistics, 2005).

In recent years, reports that the United States may be losing its foothold as the nation's leader of science and technology have fueled much debate from within the walls of the Washington to the confines of the teachers' lounge. The most notable of these reports came from an executive summary generated in 2005 by The National Academy of Sciences, The National Academy of Engineering, The Institute of Medicine, and the National Research Council. In a document entitled, "Rising Above the Gathering Storm: Energizing and Employing America for a

Brighter Economic Future," these US Academies reviewed trends in the United States and abroad. These trends generated deep concern that the "... scientific and technological building blocks critical to our economic leadership are eroding at a time when other nations are gathering strength" (Committee on Science, Engineering, and Public Policy, 2007).

While it may not be reasonable to blame this slippery slope entirely upon the K-12 education system, it does seem reasonable that this may be a place to start. In 1996 the National Science Education Standards were published in a collaborative effort between the American Association for the Advancement of Science and the National Research Council. In addition to addressing specific science content, the Standards focus a great deal of attention on the need for students to develop their understanding of science by combining scientific knowledge with reasoning and thinking skills, to use critical and logical thinking, and to consider alternative explanations. Recommendations for reform in science education place a premium on students' understanding of scientific concepts and their ability to identify problems, conduct inquiry, and use information flexibly. They call for an appreciation for how ideas evolve and are validated (Marx, 1997).

For so many Americans, science education has encompassed hours of memorizing foreign vocabulary, test after test requiring memorization of strange terminology, describing functions and structures of things that could neither be seen nor imagined. This traditional approach to teaching science is rooted in presenting scientific knowledge through lecture, text, and demonstration. Traditional science teaching tests students for factual information at the end of a unit or chapter, is inclined to rigidly follow curriculum, and is predominantly teacher-centered. Few students in these classrooms have ever learned science through active and extended scientific inquiry - an approach promoted by those who teach within a constructivist framework.

Problem-based learning (pbl) is one pedagogy that is designed to address reform recommendations, and is organized by investigations to answer driving questions, promote collaboration among learners, introduce the use of new technology, and facilitate the creation of authentic artifacts that represent student understanding (Marx, 1997).

Statement of Research Question

What is problem-based learning in science and does it facilitate scientific literacy of our students? As citizens, we are confronted with everyday decisions that require scientific understanding to make informed decisions - questions that are not only directed to the scientific "elite." Our students must become proficient problem-solvers and critical thinkers. Indeed, it is the collective judgment of everyone that will impact how the nation as a whole uses and manages shared resources, such as water, air and national forests.

Will students in a middle-school classroom, who learn science within the framework suggested by problem-based science instruction, develop an appreciation and passion that will sustain them through high school and into their adult lives? Said another way, if we recognize that the state of our current science education has resulted in an increasingly scientifically illiterate nation, can we afford to not take a look at how our students are learning science?

Problem-based learning is a constructivist approach to teaching science that promotes student understanding and use of scientific knowledge. Opportunities for scientific discussion and debate among students are infused throughout the curriculum. Students are continuously assessed for understanding, where assessments align within the context of their learning. True, none of these ideas or discussions could come about without content knowledge, but new knowledge comes about through experimentation and exploration, in other words, through playing the game of science. While constructivism is considered a theory, problem-based learning is one mode of teaching that fits the criteria of this school of thought.

Organization of Chapters:

Chapter two defines problem-based learning, describing the five essential elements - the driving question, inquiry and investigation, collection of artifacts, presentation of findings and collaboration. Chapter three presents the reader with four case studies from the literature that describes how pbl was used in the classroom. In each example, all five elements of pbl are highlighted illustrating how each of these components played out and relative significance of each. The fourth chapter provides an analysis of the case studies described in chapter three, comparing the five elements across all four studies in terms of their success or failure and importance to the overall study. The final chapter provides a description of how problem-based learning will be infused into my own 7th grade science classroom.

Definition of Terms

Active learning: Any instructional method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing (Bonwell, 1991). While this definition could include traditional activities such as homework, in practice active learning refers to activities that are introduced into the classroom. The core elements of active learning are student activity and engagement in the learning process. Active learning is often contrasted to the traditional lecture where students passively receive information from the instructor (Prince, 2004).

Collaborative learning: Any instructional method in which students work together in small groups toward a common goal. As such, collaborative learning can be viewed as encompassing all group-based instructional methods, including cooperative learning (Millis, 1998). The core element of collaborative learning is the emphasis on student interactions rather than on learning as a solitary activity.

Cooperative learning: A structured form of group work where students pursue common goals while being assessed individually (Millis, 1998). The core element held in common is a focus on cooperative incentives rather than competition to promote learning.

Problem-based learning (pbl): An instructional method where ill-structured problems are introduced at the beginning of the instruction cycle and used to provide the context and motivation for the learning that follows. It is always active and involves significant amounts of self-directed learning on the part of the students (Prince, 2004). It is a process of learning where a case problem is presented to students who are asked to apply reasoning, questioning, researching, and critical thinking to find a solution to the problem. It is "focused, experiential learning (minds-on, hands-on) organized around the investigation and resolution of messy, real-world problems" (Torp and Sage, 2002)

Chapter Two
What is Problem-based Learning?

In the following chapter problem-based learning will be defined, and four research studies presented that examine how this method of teaching science has been implemented in middle school classrooms. All four of these studies exemplify different strengths and weaknesses and are infused with both student and teacher comments that enable the reader to gain some insight into their respective perceptions of living inside these studies.

The chapter will begin with a presentation of the origin of problem-based learning, leading into a description of the essential elements characteristic of problem-based learning: The driving question, inquiry and investigations, collection of artifacts, presentation of findings and collaboration. The research studies that follow will elucidate all of these elements - how each of the criteria played a part in the pbl units developed by the teachers.

The Origin of Problem-based Learning:

Problem-based learning has its roots in medicine developed to increase the performance of medical students. In the medical field, pbl models are case studies, where students are faced with short vignettes of a patient suffering from specific symptoms. Medical students are asked to use these clues to delve deeper into the case to uncover the disease or condition, make a diagnosis and prescribe a plan of action. When student performance of medical students exposed to pbl was compared to those students receiving more traditional teaching methods, the data revealed that the pbl students scored slightly higher on achievement tests, but the real gains were noted in the pbl students' performance-based skills that are required of practicing physicians (Torp & Sage, 2002). This model has since transferred to education outside of the medical field.

What does problem-based learning look like in the K-12 classroom?

No matter what the literature has to say about problem-based learning, it is almost always aligned with the constructivist pedagogy. However, unlike constructivism, which is often difficult to define, means different things to different people and exists within a continuum, problem-based learning is well-described, clearly defined and composed of very specific elements.

Problem-based learning is an instructional method in which students learn through facilitated problem-solving. During pbl, student learning centers on a complex problem that often does not have a single correct answer. This is often referred to as an ill-defined problem. Students work in collaborative groups to identify what they need to learn in order to solve a problem. They engage in self-directed learning and then apply their new knowledge to the problem and reflect upon what they learned and the effectiveness of the strategies employed.

The teacher acts to facilitate the learning process rather than to provide knowledge. The goals of pbl include helping students develop 1) flexible knowledge, 2) effective problem-solving skills, 3) self-directed learning skills, 4) effective collaboration skills, and 5) intrinsic motivation (Hmelo-Silver, 2004).

In pbl, students encounter a problem as it occurs in the real world, outside the classroom. There is insufficient information to develop a solution, no single right answer or strategy, and a need to redefine the problem as new information is gathered. This also characterizes science, which one scientist describes as *"a process of thinking about problems then designing means of approaching them... not necessarily to solve the problem you outlined, but to make an inroad or a start, asking what further approaches can I use to get a handle on this problem?" (Greenwald, 2000)*

Problem-based learning is a comprehensive approach to classroom teaching and learning that is designed to engage students in the investigation of authentic problems (Blumenfeld, 1991). The American Association for the Advancement of Science and the National Science Teachers Association both comment that learning needs to occur in the context of real investigation through inquiry and reasoning. Given this, it becomes essential that we teach for understanding and not mere memorization of facts.

Depending upon who or what is read, the vocabulary may vary slightly, but the message is consistent with respect to the elements that pbl must contain. These elements occur in a specific sequence and read as follows:

1. Driving question
2. Inquiry and investigation
3. Collection of artifacts
4. Presentation of findings
5. Collaboration - this runs throughout the process.

The Driving Question

At the heart of true pbl is an ill-defined problem, an unresolved "murky" situation. This is presented to small groups of students who have been given a stakeholder role which is the "hook," says Gallagher (1995) that propels and invests students in the ill-defined situation. The nature of an ill-defined problem is one that students know little about, need to establish what they need to learn, and determine how they intend to get the bottom of the problem.

Problem-based learning seeks to overcome the disconnect that too often exists between the classroom and the real world. To this end, the driving question seeks to narrow this gap by asking authentic questions that bring relevance to the classroom. Marx (1997) describes three essential characteristics of good driving questions. First, they need to be worthwhile in that they are consistent with existing curriculum frameworks. Second, driving questions need to encompass real-world problems that students find meaningful, thereby motivating them to take ownership of the questions and to thoughtfully pursue answers to them. Third, questions need to be feasible; students need the prerequisite knowledge and skills to design and conduct investigations to find answers to their questions, but not enough background knowledge so as render the question moot.

Questions like "What is air?", while they involve important science content, are not authentic. The same content can be learned and more authenticity afforded by a question like, "Will breathing the air in my city make me sick?" Similarly, the question, "What are Newton's laws?" involves substantial science content, but the question "How do I stay on my skateboard?" relates this science content to the lives of students (Marx, 1997).

In pbl, the problem is ill-defined, which is typically how problems present in science. The "problem" is unclear and raises questions about what is known, what needs to be known, and how to find out. This opens the way for finding *many* problem possibilities (Greenwald, 2000). It is essential that students do not have enough prior knowledge to solve the problem. The very nature of the ill-defined driving question is that students will have to gather the necessary information, collaborate with one another, access new information, and learn new concepts in order to address the problem.

White (1995) describes a good problem as typically involving a real situation, sequential components, and sufficient complexity to engage a group of students productively for up to a week or more. Case studies in business and medicine have these qualities. They require students to gain understanding, apply multiple concepts, and make decisions based on their work.

Inquiry and Investigation:

Well-conceived and authentic investigations provide opportunities for students to engage in scientifically important endeavors like planning and designing experiments, searching for information in libraries and electronic sources like the World Wide Web, observing natural phenomena, collecting and analyzing data, developing explanations, drawing inferences and conclusions, and reporting findings to others (Marx, 2007). Marx goes on to describe a project called "Is the water in Traver Creek safe?" one of the major investigations was to map a section of the creek, identify and measure pollutants, derive a water quality index, and monitor populations of benthic macroinvertebrates.

An illustration of how inquiry and investigation can happen can be described through Project EXCITE, a seven year professional development project funded by the National Institute of Environmental Health Sciences. (http://www.bgsu.edu/colleges/edhd/programs/excite/). This web page provides examples of inquiry investigations taking place within pbl units. One such pbl project exemplifies the kinds of inquiry investigations that can accompany a thoughtful driving question.

This project is designed for middle school students who are asked to be consultants for an area farmer. The farmer has noticed that his crop yields have been declining every year for the last decade. As agricultural consultants, the students' are charged with diagnosing the farmer's problem and are to prescribe a plan of action for the improvement of his crop yields.

The inquiry investigations that students could potentially conduct include researching agricultural practices, crop yields, horticulture, annual weather reports, and water and soil quality. These investigations can be conducted through a variety of methods, such as interviewing agriculture specialists or farmers, reviewing historical weather reports, comparing the results of different agricultural methods, or even performing water/soil quality tests. Students may choose to conduct different "controlled investigations" designed around crop growth.

Students may attempt to grow a specific crop in different soils, varying the nitrogen levels, or they may conduct field research, relating the crop yields of several area farmers to those farmers' methodologies and/or the composition of their fields' soil. This problem presents many research avenues for the students and several feasible solutions to the problem. Like a true problem-based lesson, the students will be driven toward specific "content goal," but their individual experience and interests will dictate their specific learning pathway.

Collection of artifacts:

Artifacts are tangible, real results of the process of investigation that represent student understanding. Artifacts can be computer programs, multimedia documents, written reports, posters, group presentations, or any complex representation (or preferably, multiple representations) of the students' thinking (Perkins, 1992). For instance, students have prepared a presentation to the local water board about results of a study of stream quality; others have designed an exhibit for the local children's museum. Middle school students make their recommendations to the school faculty and board members on ways to improve sanitary conditions in their school.

Presentation of Findings:

Because they are tangible, artifacts can be shared and critiqued by other members of the learning community in a manner similar to scientists sharing their work within research communities (Marx, 1997). Communicating findings is a critical component of the scientific community and is not one that is easily emulated in a classroom setting. Problem-based learning factors this element into the method. Because they are tangible, the artifacts and the presentations themselves can be used to assess student learning, giving teachers the opportunity to provide feedback in perhaps a more familiar way.

Collaboration.

Marx (1997) speaks to the role of collaboration within the context of pbl. In pbl, the classroom environment is structured so that students work in groups, where the group activities foster collaboration-literally laboring together to accomplish a task. Collaboration is such an essential component of pbl, that all the literature regarding pbl makes mention of it. Collaboration affords the learners opportunities to share ideas, extend their thinking, draw on the expertise of others, and experience the value of thinking intelligently (Bruer, 1995).

Marx (1997) goes on to distinguish between the difference in collaboration and cooperation. The latter is often highly structured and students are assigned roles, tasks, and procedures. The tasks are generally designed to help students learn information already presented. In contrast, collaboration is more loosely structured with roles largely negotiated among participants. Cooperation focuses on small groups within the classroom; collaboration envisions a wider sphere of communities of learners.

Teachers and students collaborate with each other as they work on investigations and artifacts; they collaborate with members of the local community (experts like the forester who works for the community's parks department or an engineer in a local company); and they collaborate with teachers, students, and with experts through telecommunications activities like participating in list serve groups on the Internet and publishing the findings of their investigations on the World Wide Web. Cooperative learning highlights sharing answers and explanations in order to learn teacher- determined concepts and procedures.

As these small groups become the focus of the learning environment in the classroom, teachers must assume a different, often unfamiliar role. Rather than being the sole content authority in directing the learning process, the teacher becomes the facilitator or coach of each small group. The type of intended collaboration in each small group includes resource identification, peer support, acknowledgment, reinforcement of existing knowledge and assistance and assurance of integrating and synthesizing new information. The formation of small groups, their dynamics, and how well they function are all important considerations in the pbl process (Lambros, 2004).

When considering the use of problem-based learning in a classroom, it will become easier to design and implement if the key elements described in this chapter are kept in mind. Understanding the characteristics of a strong driving question, the possibilities for authentic inquiry and investigations, the options for artifact collection and presentations and the importance of collaboration, will significantly increase the probability of successful student outcomes.

Chapter 3
Investigations in Problem-based Learning

This chapter will focus on four articles reported in the literature that examine the use of pbl in the classroom. While in each case an overview of the research question being asked and respective outcomes will be provided, the focus of the writing will be to highlight the five key elements of pbl detailed above. The intent is to see how each of the components, the driving question(s), inquiry and investigation, artifacts, presentation of findings and collaboration played a role in the design and outcome of each study, so as to compare and analyze the relative significance of each in the subsequent chapter (Chapter 4).

Case Study 1: Problem-based learning and assessment in middle school

Overview of the study:

Pederson and Williams (2004) compared how three different assessment methods used during a student-centered pbl program impacted the quality of the solutions produced by students. Three classes of seventh graders used Alien Rescue, a hypermedia problem-based learning program, spanning three weeks in their science classes, all taught by the same teacher. All three groups were asked the same driving question, provided access to the same resources, required the production of artifacts, and participated in a factual multiple choice test upon completion of the program.

Students participating in the traditional assessment group produced artifacts and worksheets, but only the worksheets were graded. The authentic assessment group also produced worksheets and artifacts, where the worksheets were not graded and students were given a grade for the quality of the artifacts produced. The authentic, student-based assessment group did not have to produce any worksheets, were required to produce artifacts that were not graded, and participated in individual- and peer-evaluations.

The results of this study failed to show the superiority of one assessment method over another in this student-centered learning environment. There were no significant differences between groups in the quality of the solutions they developed. This being the case, the authors make the case that even teachers who are unwilling to part with familiar assessment methods grounded in traditional teacher-directed approaches may be able to successfully implement these student-centered approaches in their classrooms.

The Driving Question:

The driving question in this study was very clearly described. Participants used Alien Rescue, a computer-based pbl program for middle school science.

Students used the program for fifteen 50-minute periods over the course of three weeks. Alien Rescue presented students with a complex problem to solve. Students were placed in the role of scientists aboard a space station who are tasked with finding new homes on worlds in our solar system for each of six extraterrestrial species aboard a spaceship in orbit around Earth. These species originated in a distant solar system that was destroyed, and after sustaining damage to their ship, entered a state of suspended animation where they must stay until they arrive on their new homes.

Students must learn about the aliens and the planets and large moons in our solar system so they can match each species to a new home world. Many small problems are embedded throughout Alien Rescue, such as a need to convert between the Kelvin and Celsius temperature scales, identify substances using their spectrograms, and interpret data returned from probes.

<u>Inquiry and Investigation:</u>

This Alien-rescue simulation was designed to have built-in support to assist students with the inquiry and investigations phase of problem-based learning. One of these resources was a simulation in which students could design probes to send to other worlds in our solar system to gather data that they were missing about those worlds. Designing probes required students to deal with a number of constraints, such as choosing the correct instrument to gather the desired data, and selecting the appropriate type of probe. An inappropriate design resulted in malfunctions or in a failure to obtain the needed information.

<u>Collection of Artifacts:</u>

Collection of artifacts is an essential component of pbl. In this study, as students worked within Alien Rescue, they generated a number of artifacts: the contents of the notebook within the program, teacher-generated worksheets, a list and description of student-designed probes, short essays addressing the solutions to the problem where students provide a written rationale as to why they placed each species on a given planet, and a culminating 25-item multiple choice factual test. Alien Rescue allowed students to print these artifacts as well as view them within the program interface. To aid students in planning their probes, Alien Rescue was structured so that students needed to write a probe mission statement. Students were expected to record what information they planned for the probe to collect. Teachers were able to use these mission statements to discuss students' designs as well as their knowledge about worlds in our solar system and science concepts related to the types of data they planned to collect.

Presentation of Findings:

Presentation of findings in this study was not described.

Collaboration:

The described collaborative component of this pbl project involved the students participating in the peer-and-self assessment group. Students in this group were assigned to teams of three or four students to work during Alien Rescue. At the end of each week, students were asked to assess their own process as well as that of their teammates. There is no mention as to how student collaboration was structured within this group and no discussion as to how and if collaboration occurred within the other two treatment groups.

Case Study 2: Problem-based learning and at-risk middle school students.

Overview of the study:

Cerezo (2004) examined pbl and how at-risk female students in the middle grade math and science classroom perceived its effectiveness. In this study, "at-risk" students was defined as those female students in danger of failing middle school math or science. The two questions asked in the study were how do middle grades math and science students who have been involved with problem-based learning perceive the changes in their learning processes, and have there been any changes in the students' self-efficacy?

Analysis of student perceptions of any such changes in their learning processes and self-efficacy was analyzed through student interviews. Data identified the components of changes in students' learning processes and self-efficacy, which included self-confidence, group dynamics, and self-motivation. Data revealed that students' perceptions indicated problem-based learning helped them to be more confident in taking control of their learning and that problem-based learning enhanced group dynamics and its effects on students at-risk. Noting positive changes in their self-confidence, students believed group involvement enabled them to be more successful in understanding their assignments.

This study involved multiple teacher participants across three middle schools, two content areas - math and science - and across three grades level - 6^{th}, 7^{th} and 8^{th}. As a result of this, the driving questions used in this study varied. The sixth grade science class implemented the pbl case "Equinox or Not?" focusing is on the seasons of the year and the equinoxes. The seventh grade math class used a pbl case named "Abbey Grange," focusing on the skills/concepts of processes of problem-solving and logical thinking. The eighth grade math class used the case "Patty O'Design" which involved the use of area, perimeter, and deductive and inductive reasoning. There were two grade eight science classes involved in this study. One used the pbl case "Your Island Factory" which focused on the concepts of the environmental impacts of industry, chemical reactions, the social perception of pollution, and up-scaling production. The other eighth grade science class used the pbl case "Beachcomber" that focuses on fossils, what they are, the difference between a fossil and a bone and the types of fossils found in North Carolina.

The Driving Question:

In this article, the authors refer to the driving questions as cases, where the teachers presented each case in steps called scenarios to each group of students. The initial phase required groups to decide upon what was known about the topic, information that was still needed to solve the case and a hypothesis. An example of one such case is provided below.

Patty O' Design - A Problem-Based Learning Case

Scenario 1: You are employed as a landscape architect. You work on the design team and your group receives this letter:

Smith-Jones Landscaping Design, Inc.
1575 East F
Forsyth Boulevard

Dear Sir or Madam:

We are interested in adding a patio to our house. We have decided that we would like to use as much as possible of the 20-foot by 20-foot area directly behind our house for a patio shaped in a nontraditional design. We would like for you to submit two designs with specifications so that we can choose the one we like better. Please be aware that we want to use at least 340 square feet of the available area for the patio. We have read your brochure and enclosed the $200 design fee. We appreciate your guaranteed delivery date of one week.

Sincerely,
Ian and Patty O'Brien

What would be helpful to know before you begin your design? How will this information help you? What will you do next?

Scenario 2

Smith-Jones Landscaping Design, Inc.
1575 East Forsyth Boulevard

Dear Sir or Madam,

This letter is to inform you of the modifications we would like to add to our original instructions in regard to your company's designing a patio for us. Looking back on our vacation photos of our trip out west last year, we were reminded of some creative yet beautiful patios we saw. We would like for you to make sure that your designs for our patio have the following features:

• We would like two areas for flowers on the sides of the patio that are adjacent to the house. Please use only about 70% of patio footage for the flower areas; then on each side extending from the house out to the yard, use about 80%.

• A small area in the center of the patio for flowers (this area should be in the same geometric shape as the patio design and about 10% of the entire patio size).

Again, thank you very much for your cooperation and understanding in this matter. We eagerly await your designs.

Sincerely yours,

Ian and Patty O'Brien

Inquiry and Investigation:

Not a great deal of detail was provided with respect the inquiry and investigation component of this pbl study. Students were able to decide what to research and how to research. Some students used written resources and some computer resources. Students did state that pbl enabled then to better utilize all available resources, be they the media center, the Internet or printed materials. .

Collection of Artifacts:

The description of artifacts that students collected was limited to the simple mention of final products being in the form of a report, a letter, or a graphic display.

Presentation of Findings:

Presentation of findings occurred on the final day. Students presented their designs individually or as groups, and explanations were required. One student commented on how she preferred the variation of the process, including the presentation of the final product where her group showed pictures for their final product.

Collaboration:

The outcome of the collaborative component was this pbl study was well described in this study. When students began to work in their groups, they were able to move about freely while the teachers were available to answer questions or provide assistance. Students divided research to complete at home and were expected to return to the group with the new information.

Case Study 3: Problem-based Learning in a Middle School: Lessons Learned (Mining for Gold)

Overview of the Study:

Gertzman and Kolodner (1996) report on a case study in one 8th-grade science class and discuss some of the specific difficulties encountered in implementing pbl and identify coping strategies improvised by teacher and students in adapting to the unfamiliar roles and expectations of the pbl approach. The report was based on field notes of daily participant observation in two classes throughout the 7-day unit, informal interviews with the teacher, and classroom artifacts.

The Driving Question:

The driving question was developed during the summer 1995 pbl workshop and modified by this teacher to augment an earlier unit on rocks and minerals that included a field trip to Dahlonega, the site of Georgia's own 19th-century gold rush. On the first day of the unit the students were presented with the problem statement: A thirteen year- old boy in North Carolina recently found a sapphire worth $33,000 in an abandoned mine. Georgia has riches too. "There's gold in them thar hills," and much of this gold is in the Atlanta area. Maybe we can get lucky too. Where might we find gold, and what areas would be worth mining? You will make a presentation to potential investors.

Inquiry and Investigation:

To carry out their own inquiry and investigations, students were provided with materials that included mineral resource maps and research materials that both the teacher and her collaborators on the EduTech staff had gathered. For this unit, students performed a lab experiment demonstrating the chemical process of reclaiming copper from a solution, an activity the teacher added to get students thinking about the environmental impact of mining.

Collection of Artifacts and Presentations of Findings:

Neither the artifacts collected, nor the details of student presentations were described in this study. The authors did state that students would be a presenting their findings to potential investors.

Collaboration:

With only one teacher for thirty students, the teacher decided to use large-group discussions to get students started in solving problems and for sharing between groups. Students would work in small groups after large-group discussions had provided them with focus. To this end, as a class, and using the white boards to brainstorm, the students made lists of facts (what they knew), ideas (related thoughts and hypotheses), learning issues (what they needed to know more about), and actions (what they needed to do), recorded their thoughts both on large sheets of poster paper tacked to the classroom wall. After identifying a number of items in each category, students broke off into small groups of 4-5 students, refined their lists, and began independent research using materials the teacher has placed on a table at the front of the room.

The teacher facilitated the large-group brain- storming sessions to keep students focused and to guide them to resources that would answer their questions. She did not give prepared lectures about the content, nor did she structure the material presented. Students discovered and recorded pertinent information through their own exploration of the resources, and they discussed findings with their group members to compile the growing list of evidence that formed the basis of their argument in the final group presentation.

Case Study 4: Cougars, Curriculum and Community

Overview of Study:

Quitadamo and Campanella (2005) teach on the eastern edge of the Cascade Mountain range in Washington State, where high school biology students have a unique opportunity to study the elusive cougar *(Felis concolor)*, a large cat native to the area. Nestled in the Cascade foothills is the city of Cle Elum, a small rural community that is expected to soon experience considerable growth from development of a large resort. The community provided an excellent model for scientific study of native animals; students can study and compare the cougar's habitat and behavior before, during, and after resort development.

When faced with a complex problem that threatens cougars, students try to find solutions that ensure the animals' continued health and conservation. In this article, the authors describe the design and implementation of the Cougar Conservation Project (CCP), a problem-based learning curriculum that provided students and community members with valuable interdisciplinary learning experiences.

The Driving Question:

The driving question in the pbl study read as follows:

"What happens when cougars, which need individual ranges of up to 160 km^2 for their survival, are confronted with a booming human population? Where do North America's largest native cats go when their habitat gives way to hundreds of new houses?" We need a plan, one based on your own knowledge of genetics and biodiversity. In the next few weeks, you will be learning about DNA, heredity, genetic variability, and much more. You will put your knowledge and research skills to the test by making a Cougar Conservation Plan for the Cle-Elum area. The current population of cougars has been dramatically reduced in numbers, something that is called a "bottleneck." We need to work fast and come up with a plan to help the cougar population regain numbers. You will research, write, and present your plan which will possibly be submitted to WDWF biologists. Good luck!

Inquiry and Investigation:

Using class discussion as a starting point for the investigation and inquiry portion of this study, each team began to further define the cougar conservation problem. Research teams, realizing that there was a general relationship between the amount of available local land and the number of cougars, began to focus on methods to determine cougar carrying capacity. Students also had to identify and evaluate sources of information (e.g., Internet, books, journals, and Washington

Department of Fish and Wildlife (WDFW) biologists as part of their research. To improve their cougar conservation efforts, research teams consulted successful conservation plans from around the world.

Artifact collection:

In addition to the conservation plan artifact, each plan of action included student cougar artwork that illustrated cougar body size and structure and provided visual context for research findings and conservation recommendations. For example, groups created trivia games, cougar pamphlets and flyers, or used computer software to create cougar animations.

Presentation of Findings:

Upon culmination of their conservation proposals, students presented their recommendations publicly to their peers, to the Washington Department of fish and Wildlife biologists, to the district leadership, to teachers and to Central Washington University faculty members.

Collaboration:

The discussion of the collaborative component of this study was limited to the mention of students working in research teams of two to four individuals to research genetic diversity and cougar behavior.

Summary:

The connections between all of these studies lies in the elements that exist within and across all four. These five elements, the driving questions, the inquiry and investigations, the collection of artifacts, the presentations, and the collaboration, play out differently in each study. In the chapter that follows, each of these five elements will be compared across each of the four studies in an effort to assess the relative significance of these five characteristics of pbl.

Chapter 4 - Analysis

Introduction:

In each of the four studies described in the previous chapter, the teachers implementing the respective pbl units all commented on aspects of the units that worked and in some cases, did not. In keeping with the existing organization and structure of chapters two and three, the five key elements of pbl will be compared across each study. This analysis will include the language used by the classroom teachers implementing the pbl units, and when applicable, that of collaborating investigators.

At the conclusion of the analysis, a table will be presented characterizing the driving questions in terms of relevance and structure, the inquiry and investigations in terms of authenticity, the artifacts in terms of tangibility and how well they represent student understanding, and presentation of findings in terms of how well they model the scientific community.

The collaborative component of each study seemed to either work or not. Collaboration, in combination with the driving question, appeared to wield the greatest influence as to how the teachers perceived the overall success of the pbl unit. Given this, the collaborative component of each pbl case study will be reported in terms of overall success.

These characterizations will be based upon the direct commentary from the authors when applicable, or from my own interpretation when authors do not speak to these elements directly.

<u>The Driving Questions:</u>

The strength of driving questions lies in their complexity and how much prior knowledge students have at the outset of the unit. Strong driving questions need to be ill-structured. Students should not have enough prior knowledge to solve the problem without having to gather new information, learn new concepts and gain new skills. Good driving questions need to be relevant, bring authenticity to the classroom and be worthwhile in that they are consistent with existing curriculum frameworks (Marx, 1997).

<u>Case Study 1 - Alien Rescue</u>

In this study students are tasked with finding the most suitable home on planets within our solar system for each of six extraterrestrial species aboard a spaceship in orbit around Earth. While the question in and of itself may not appear relevant in that it attempts to close the gap between real world science and the classroom, the process of finding the solution, makes it very authentic - students are placed in the role of scientists placed aboard a space station, are expected to keep lab notebooks, expected to document their findings, design probes to collect data, make hypotheses and deal with constraints. This driving question certainly remains consistent with the earth science curriculum requirements for this district and is structured in a way that students will not be able to solve the problems without seeking new resources.

Case Study 2 - Patio Construction:

In the second study, one group of math students were asked, as architects, to develop and present a design for a patio addition for a client. This problem speaks to all the characteristics of a good driving question - students have to use and apply their mathematical knowledge, seek additional resources, and are able to see the real world application of this kind of problem bringing relevance to the classroom. In response to interview questions as to why the students enjoyed pbl, students commented on how the challenge of the case(s) sparked the interest of some of the participants and how they were being challenged to think differently and be open to new ideas. One student commented on how she felt it to be so focused on opinions and real-life situations. "We have times we get to ... [state] ...our opinions on different stuff in the world, to get a chance to do work, working with things that happen and occur in the world."

Case Study 3 - Mining for Gold

In the third pbl unit, the teacher expressed perplexity by what she called the "wording" of the problem statement, in that it lead students to focus on economic rather than environmental questions concerning the mining of gold. The authors suggest that a major issue was the lack of correspondence to curriculum goals. This is an unfortunate, but necessary part, of developing problems for use in classrooms. It would seem that this problem might go away as problems are better developed, but the authors believe this issue will only show up in a different guise; as careful as one might be in putting problems and materials together, teachers will often have to adapt them for the idiosyncrasies of their own curriculum guidelines and classroom environments.

The students also encountered difficulties with the pbl approach. The most noticeable issue was their initial uncertainty about the problem statement and what was expected of them. Though the teacher carefully explained the steps they would undertake, the open-endedness of the problem was daunting, and many students were either passive or openly resistant.

An essential element of pbl is to "bring the problem home" to students, to make a connection with their real-world experience, but these eighth-graders have seen the abandoned gold mines in north Georgia and have heard their tour guide tell them there's not enough gold to warrant further efforts at extraction. Thus the gold problem was an exercise in fantasy, not a potential real-world puzzle, and their primary goal became one of satisfying the teacher with the minimal effort required (Gertzman and Kolodner, 1996).

Case Study 4 - Cougars and Curriculum

In the fourth study, students are faced with a complex problem that threatens cougars, and they are to try to find solutions that ensure the animals' continued health and conservation. Here, an intentionally unstructured genetics bottleneck scenario was presented to students. The authors commented that although this resulted in some distress because the driving question was not prescriptive, student involvement and work quality increased. While there is no definitive explanation for why this occurred, the authors comment that it is reasonable to suggest the process of solving an authentic problem facing the community, working in small collaborative teams, and providing an interdisciplinary context effectively engaged students.

Inquiry and Investigations

As Marx (2007) reminds us, well-conceived and authentic investigations provide opportunities for students to engage in scientifically important endeavors like planning and designing experiments, searching for information in libraries and electronic sources like the World Wide Web, observing natural phenomena, collecting and analyzing data, developing explanations, drawing inferences and conclusions, and reporting findings to others.

Case Study 1- Alien Rescue

Students involved in this pbl unit were actively involved in a simulation where they were required to design probes to send to other worlds in an attempt to gather data about the new worlds. This type of investigation required students to deal with a number of constraints including the need to choose the correct instrument to gather the desired data. In addition, students were expected to select the appropriate type of probe based on which instruments were used, with an inappropriate design resulting in malfunctions or in a failure to obtain the needed information. The students commented on this opportunity for active learning in a positive manner stating that this was a better way to learn science than simply reading out of a text book.

In this pbl unit, students are given the opportunity to engage in scientifically important endeavors, thereby meeting the criteria for authentic investigations, one hallmark of problem-based learning.

Case Study 2: Patio Construction

Very little was described in terms of the inquiry and investigations conducted by students in this pbl unit. Short of the comments made by the students regarding their increased knowledge of utilizing references and accessing media in the library and on the Internet, the authors did not lend much voice to this component. In this case, given the overall success of his unit as perceived by the students and the teachers, one can infer that the investigative component was neither solely responsible for the success of the unit, and certainly cannot be seen as a limiting factor.

Case 3: Mining for Gold

Student investigations for this unit included the exploration of resources including mineral resource maps. As new information was gathered, students would record the pertinent information and discuss their findings with their group. In addition, students also performed a laboratory experiment demonstrating the chemical process of reclaiming copper from a solution. The intent here was to get students thinking about the environmental impact of mining for gold.

The teacher implementing this unit felt that the availability of the mineral resource maps enabled students to "find" the gold without having to learn about the geological processes that determine the types and locations of mineral deposits. In addition, she felt that the research material she and her collaborators compiled for the students did not provide the details about the geological processes. Instead they had a tendency to steer the students towards the legal issues and mining techniques.

These inquiry and investigations resulted in content goals being replaced by tangential issues. The authors suggest that a general lack of research skills contributed to this detraction from the content goals. Students spent a great deal of their time flipping through the pages of texts and journal reprints without knowing what they were looking for. Students tediously copied lists counties where gold had been found in Georgia, with no student attempting to analyze the quantity or the quality of this regional distribution of gold deposits.

Gertzman and Koldner (1996) state that these research skills, such as how to look for information and how to determine what information to look for, are skills that are explicitly taught as students learn to think critically, questioning and analyzing information and looking for potential bias in their sources.

<u>Case Study 4: Cougars and Curriculum</u>

Investigations and inquiry carried out by students for this unit included collaborative group research with research teams of two to four students identifying and evaluating sources of information including the Internet, books, journals and biologists. What made this part of the unit more successful than the gold mining study described above was the use of a class discussion as a starting point. It was during this discussion that the students began to further define the driving question regarding cougar conservation problem.

Collection of Artifacts

As Perkins (1992) reminds us, artifacts need to be tangible, real results of the process of investigation that represent student understanding and thinking.

Case Study 1: Alien Rescue

The notebooks that the students kept to record notes on the needs of the alien species, facts about worlds in our solar system that related to these needs, and any hypotheses or questions students had, mirror those of records that might be kept by scientists charged with this mission.

Students designed probes to gather data from various planets in order to asses the best new home for the alien species. It is in the design of the probes that the real learning came. The students were required to deal with a number of constraints, such as choosing the right instruments to gather the desired data and selecting the appropriate type of probe based on the instruments used. These artifacts are tangible representations of student understanding.

Case Study 2: Patio Construction

The description of artifacts that students collected in this study was limited to the simple mention of a report, a letter, or a graphic display. These artifacts are in-keeping with those of an engineering company presenting ideas to a potential client and have the potential for assessing student understanding of the content.

Case Study 3: Mining for Gold

There is no mention as to any specific artifacts that students were to generate in this study. Students were required to make presentations to potential investors as to what areas would be worth mining for gold. This suggests that students did produce some form of tangible artifact such as posters, power points, maps, but in the absence of this information, no characterization as to this component can be made.

Case Study 4: Cougars and Curriculum

Throughout the process of generating conservation plans for the cougars, research groups were able to consult successful plans from around the world. The authors comment that by comparing their work to that of conservation experts, students could gauge their own skill and determine which specific factors would contribute the success of their own plans. Through the generation of this artifact, students developed global conservation awareness that related directly to their high school awareness.

As previously mentioned, in addition to the conservation plan artifact, each plan of action included student cougar artwork that illustrated cougar body size and structure and provided visual context for research findings and conservation recommendations. For example, groups created trivia games, cougar pamphlets and flyers, or used computer software to create cougar animations. All of these artifacts provide tangible evidence of student understanding of the conservation issues.

Presentation of Findings

Marx (1997) reminds us that because they are tangible, artifacts can be shared and critiqued by other members of the learning community in a manner similar to the way that scientists share their work within research communities. Presenting research findings is at the core of the scientific community. If important findings are not communicated both within the scientific community and the public domain, important change cannot be afforded. Emulating the sharing of scientific findings within a classroom is often overlooked and when it is included as a part of the curriculum, can often feel contrived.

Case Study 1, 2 and 3:

In all three of these cases, presentation of findings was either not addressed at all as was the case for Alien Rescue, or very little information was provided as in the cases of Patio Construction and Mining for Gold. For the study, where students were hired as engineers to design a patio for a customer, there is mention made of student presentation of their design at the culmination of the unit. Short of this, there is no detail as to what the presentation would embody. Having said this, the potential for these presentations to emulate those made by an actual architectural firm, are very high. It is possible that students could or would have presented their blue prints or a floor model. Both of these options would reflect student understanding of the assignment as well as reflect the type of presentations made by working engineers.

For the Mining for Gold case, students were expected to make presentations to potential investors as to where gold might be found and the exact areas worth mining. No additional details are provided as to the exact content of these presentations. The realm of possibilities may include maps of the area, geological processes at play that would make the land conducive for mining, and the costs involved.

Case Study 4 - Cougars and Curriculum:

Of the four pbl units described, this one truly emulates the kind of presentations that would mirror those made by the scientific community. Student research teams communicated their conservation plans not only to their peers but to *the* WDFW biologists, the Project Coordinator, District Leadership, and to other teachers and faculty. As pointed out by the authors, the nature of these presentations addresses an authentic biological problem that concerned the entire Cle Elum community.

Collaboration:

As previously described by Lambros (2004), the type of intended collaboration in small groups includes resource identification, peer support, acknowledgment and existence reinforcement of existing knowledge, and assistance and assurance of integrating and synthesizing new information. The formation of small groups, their dynamics and how well they function are all important considerations in the pbl process. As these small groups become the focus of the learning environment in the classroom, teachers must assume a different, often unfamiliar role. Rather than being the sole content authority in directing the learning process, the teacher becomes the facilitator or coach of each small group.

Case Study 1 - Alien Rescue

The collaborative element of this pbl study played out within teams of three or four individuals. At the end of each week, each student was asked to assess their own process and as well as that of their teammates. For example, students included a score on willingness to collaborate and participate in class discussions, as well as scores on how well they had met benchmarks the class determined to be reasonable for the week. Then at the end of the week, students were given a form listing these criteria and asked to score their own work and that of their teammates on a 0 to 5 point scale. Students were given a cumulative grade based on this evaluation, but they were not told which of their teammates had assigned which scores. The authors did not publish the results of these evaluations and in the absence of this data, it is not possible to draw any conclusions as to the significance, or lack thereof, of the collaborative element.

Case Study 2 - Patio Construction:

The nature of the collaboration that occurred within this pbl unit requiring students to design a patio was highly successful. In response to interview questions as to why they liked the pbl format, students cited being able to work in groups and be supportive of one another as one of the reasons. Two students in the same science class commented on how the collaborative group environment was non-threatening, and allowed students to have the opportunity to come up with new ideas and to express these ideas. Another student commented on how the small group collaboration "kept her on her feet" given the responsibility of "...finding stuff" for other people. "It keeps me on my feet. I have to turn it in at a certain time and I work better if I'm pressured. I have to find stuff for other people, which I like doing. I like it."

Participants indicated that working in groups was of a great benefit to their learning process and assisted them in developing a respect for others and listening to what they had to say. Most stated they became better group participants through the pbl process. Cathy (grade eight) and Molly (grade six) both felt the opportunity to work with others affected their performance in school. "You can get closer to people, people that you don't know, you might get to work in a group with them, be able to get along with more people ... It helps a lot with your school work and how to work with people" (Cathy). Molly stated, "I do better with pbl, because since it is a group activity, you get more than just your opinion, so it's a wide range of opinions."

Case Study 3- Mining for Gold:

The small-group collaborations caused problems for many students in the Gold Mining pbl unit. Although the teacher felt that the collaborative process worked well overall and that students seemed able to adjust to their group situations, there were numerous conflicts with the gathering, sharing, analysis and presentation of information, and also with interpersonal dynamics within groups. The students' general lack of research skills meant that they spent their time aimlessly flipping through pages of texts and journal reprints without knowing what information they were looking for, taking notes on easily recognizable data but failing to ask questions that would lead them to a deeper understanding of the issues. Virtually every group, for example, tediously copied lists of counties where gold has been found in Georgia, but none attempted to analyze the quantity or quality of this regional distribution of gold deposits. In addition, rather than dividing research issues among group members, students tended to duplicate each other's work.

Issues of gender and leadership also arose, with boys tending to push for decisions early in the process (often before doing much research) and girls assuming the passive role of group recorder. In two groups, acrimonious disputes ensued when the boys dominated the discussion and forced the girls on the team to acquiesce to their preferred conclusion, despite a lack of solid evidence. Finally, a number of groups had difficulty completing their assignment because of the uncooperative or inattentive behavior of one or two members who sabotaged the group's efforts.

With thirty or more students packed into her small classroom, the task of maintaining order and concentration among these teenagers was intimidating. "It's really an art," the teacher reveals, referring to the challenge of arranging groups to maximize cooperation and learning amongst the members.

The unsuccessful implementation of the Gold Mining unit warrants further discussion. The teacher was very articulate as to the specific causes of the shortcomings of this unit. She felt that:

> "... the content goals she identified in planning this unit have been replaced by tangential issues, and that the customary authority she has as teacher to redirect students' attention is not available in her role as pbl facilitator. She was uncomfortable with this loss of control, explaining that she is accustomed to "chunking off" bits of each topic so that students are introduced to concepts gradually and can build new knowledge on the old. "I need some more help or input with how to tier the problem, to find a way to make those two or three major facets of the problem more obvious," she says.

Case Study 4 - Cougars and Curriculum

In the cougar conservation pbl unit, the authors attributed the success of this pbl unit to the small group collaborative learning which was thought to have had a positive effect on student learning. Peers at similar developmental levels constructed knowledge through their own social interaction. By teaching others within their group, students may have reinforced their own knowledge about genetics and cougar conservation.

Summary of Analysis:

Table 1 presented below, provides a summary of this chapter, characterizing the driving questions in terms of relevance and structure, the inquiry and investigations in terms of authenticity, the artifacts in terms of tangibility and how well they represent student understanding, and presentation of findings in terms of how well they model the scientific community. The collaborative component of each pbl study is simply defined in terms of success.

Table 1:

pbl Study	Driving question(s)	Inquiry and Investigation	Artifacts	Presentation of Findings	Collaboration	Successful or not?
1 - Alien Rescue	Ill-structured, relevant	Authentic	Tangible, represent student understanding	Not described	Limited discussion	YES
2 - Patio Constructi on	Ill-structured, relevant	Not well described	Tangible, represent student understanding	Not well described	Highly successful	YES
3 - Mining for Gold	Ill-structured, not relevant	Not authentic	None mentioned	Not well described	Unsuccessful	NO
4 - Cougars and Curriculum	Ill-structured, relevant	Authentic	Tangible, represent student understanding	Models those used in scientific community	Limited discussion	YES

The prevalent characteristics of pbl studies seems to be connected to the driving questions and collaborative efforts of the groups. The entire unit pivots around the central question. If the question is not relevant for the students, as was the case with the gold mining unit, the entire exercise can end up being an exercise in giving the teacher what he or she wants in order to get the grade. By the same token, a driving question that is either too ill-structured or one that can be too easily answered, can serve to either frustrate students or under-challenge students respectively.

The collaborative component appears to have a significant role in the demise of problem-based learning. When the units described above seemed to go wrong, it was the collaboration that lay at the center of its demise, as was the case with the Mining for Gold unit. The human element of people working with people, laboring together to accomplish a task, is enormously influential. When it works, it seems to go unnoticed. When it does not, it seems to be difficult to ignore.

As Bruer (1995) reminds us, collaboration affords the learners opportunities to share ideas, extend their thinking, draw on the expertise of others, and experience the value of thinking intelligently (Bruer, 1995). The unstructured roles that exist within collaboration takes skilled negotiation from participants and the personalities at play within these groups will result in successes or conflicts, as clearly demonstrated in these pbl cases.

Chapter 5
Application within a 7th Grade Science Classroom

Background:

I plan to implement a problem-based unit in my 7th grade science classroom in the up-coming school year. This unit, entitled Bioterrorism and Real World Science has been adapted from the unit developed by Carla Johnson, a seventh grade science teacher in Cincinnati, Ohio (Johnson, 2003). Immersing students in a topic that makes headline news provides a relevant context that is the hallmark behind problem-based science teaching. With the recent SARS outbreak and anthrax scares, we have been forced to focus on the topic of bioterrorism as a threat to our nation's health and as a matter of national security.

My students spend half of the academic school year studying the life sciences. This unit will be the culminating experience where students use their prior knowledge of cellular structure and function, human physiology and critical thinking skills to assume the role of teams of investigative scientists who are employed by the Centers of Disease Control (CDC) in Atlanta, Georgia. Teams of CDC scientists will work together to diagnose the cause of three mystery diseases, justifying their diagnoses with evidence processed from the scene of the simulation. Teams will assess the risk of widespread disease, making recommendations to CDC Headquarters and essential members of the community as to how best to treat and contain the spread of the diseases. As the unit is described, I will emphasize how and when the five key elements of pbl are utilized and introduced.

The Driving Question:

The driving question for this unit reads as follows: "You and your team of scientists are being flown in from the Centers of Disease Control in Atlanta, Georgia to investigate three, as of yet; unknown diseases in a small Midwestern community. Upon arrival at your destination, the local city authorities will have set up a biohazardous "hot zone," complete with a shower, tents, protective Tyvek suits, face masks, booties and non-latex gloves. You will be given investigation directions to read on the plane. This is a very time sensitive case and you cannot wait for the patients' laboratory reports to arrive at the CDC before your departure. All this information will be made available upon your arrival at the scene. All three patients are currently quarantined at the local hospital. The medical staff is awaiting your expertise in diagnosing the diseases, and making recommendations for containment to prevent a possible outbreak if needed." Note to the reader: See addendum 2 for the investigation directions.

In the spirit of pbl, the problem is stated as an ill-structured task. In order to solve the problem, students will need to immerse themselves in the content, construct their own understanding and develop their own solutions. This will, in all probability, be the first time these students will have been exposed to problem-based learning and they will therefore need significant support and scaffolding throughout the exercise. To this end, the unit will be front loaded prior to putting the driving question in front of student teams.

Introductory Activity:

One week prior to the simulation students will "contract" a disease by randomly drawing the name of either a contagious or non-contagious disease. After making a sign indicating the name of their disease, students will gather in a circle and embark on a discussion as to which diseases they are more afraid of and why. The intent here is to introduce the concept of infectivity and the impact of transmission within and across communities. Students will have little to no background as to many of these diseases and so anticipated student responses will be those that speak to their emotions rather that factual content.

Setting the stage - Request from the CDC

This will be first opportunity for students to engage in *inquiry and investigation,* to generate *artifacts,* and begin to *work collaboratively* in small groups of three students each. Upon completion of the introductory exercise, students will receive a simulated letter from CDC headquarters, requesting their assistance in the compilation of a Student Disease Handbook (see Addendum 1). According to the letter, the handbook will be shared with school across the nation in order to better inform students as to the many diseases they could encounter around the world. These handbooks will also be placed in the simulated biohazardous zone to be used as a resource later the following week. Each student will be assigned three diseases to research. With an average class size of 30 students, each disease will be researched by three students who will initially work independently and then collaborate to compare their information. A one page data sheet will be created that addresses the following data:

- Disease Name
- Contagious or non-contagious
- Causative agent (name of bacteria, name of virus, name of parasite, genetics)
- Image of causative agent (if applicable)
- Mode of transmission (body fluids, genetics, environmental)
- Symptoms
- Treatment
- Method of containment if applicable

All finalized data sheets will be incorporated into a power point, and each group of three students who are now considered experts about their three diseases, will present the information, educating classmates. The data sheets will then be compiled into six Student Disease Handbooks, to be positioned at the laboratory stations within the soon to be created simulated biohazardous "hot zone." It is anticipated that this activity will be completed in one week, with five forty-six minute periods per student. This Disease Handbook will be an artifact that can be graded.

The Outbreak: Introducing the Driving Question

Upon completion of the Student Disease-Handbooks, students will each receive a letter from the CDC in a sealed envelope with a "confidential" stamp printed on the front face. Students will be addressed as Dr. "insert student's surname" and a title, for example, "Director of Infectious Diseases." Given that the students will be assuming the role of CDC employees, the letters will appear as inter-office communication. Each envelope will contain a copy of the driving question, described above. When all students have had the opportunity to read through the letter describing their mission, Investigative Teams will be assembled. These Teams will have been predetermined by the teacher. The original teams of three experts will be disbanded and reassigned to Teams of four investigators, so each new Investigative Team will be knowledgeable about twelve diseases as opposed to three.

The newly formed Investigative Teams will each receive a copy of the investigative directions to peruse on route to the scene (see Addendum 2). These directions prepare them for what they will be walking in to, including the protocol for entering the simulated biohazardous "hot zone," time limits placed upon each Team, what they can expect to find at each of the three stations, expectations of professional conduct and the role of the teacher.

Inquiry and Investigations:

When students return to school the day after reading their Investigation Directions, the classroom will have been transformed into a mock "hot zone" complete with personal protective gear and a decontaminating "shower" constructed out of PVC pipe and plastic shower curtain liners. Local environmental companies can be contacted to make donations of personal protective gear. The area will be identified with the appropriate biohazard posters and caution tape will be positioned.

Inquiry and Investigation: Examining the Evidence

Three stations will be constructed within the classroom. At each station Teams will be provided with the patient case history, essential evidence, and tools with which to process the evidence, resources including the Student Disease-Handbooks created earlier, and a laboratory report template. Teams must assess each of the three situations, decide how and what evidence to process, and complete the report template. The initial reports will be completed within the "hot zone" and will serve as drafts. Teams will be given time the following day to craft final reports to be submitted to the Director of the CDC. Each of the three laboratory report requests the following information:

- What is your diagnosis of the patient?
- What resources or tests did you utilize to make this diagnosis?
- What is your evidence that supports this diagnosis?
- What additional information might have useful in assisting your Team with making this diagnosis?
- What are your recommendations to the community with respect to a possible outbreak? To whom would you make these recommendations?

STATION 1: (Anthrax)

When Teams approach this station they will encounter the following items:

1. The patient case history
2. Four microscopes
3. Physical evidence to process
4. Blank Laboratory Report Template
5. Two copies of the Student Disease-Handbooks

Case History:

Mrs. Vi Rus came down with a cold all of a sudden, two days ago. She woke up this morning and had trouble breathing. She has never smoked, although her husband, who recently passed away from lung cancer, smoked for the duration of their 45 years of marriage. At her daughter's urging, she made an appointment with her family doctor. Her doctor prescribed lots of fluid, plenty of rest and advised her take two Tylenol and something to suppress her coughing. Mrs. Rus was too ill the next day to volunteer at the local library, and she called her friend, Dizzy Ease to fill in, handling all of the mail for the remainder of the week. Over the course of the next week, Dizzy Ease suffered the same symptoms as Vi, only without the raised itchy bumps Vi now had on her hands. When Mrs. Vi Rus was taken by ambulance to the local hospital, she was immediately placed in quarantine, where she remains unresponsive to the steroids she has been placed on to help reduce the multiple raised itchy bumps that now cover her hands and face. She continues to have difficulty breathing.

Physical Evidence to Process

1. Samples of the mail collected from the library where both women volunteered.

2. Photographs of the itchy bumps from Mrs. Vi Rus' hands.

STATION 2 :(*E-coli*)

When Teams approach this station they will encounter the following items:

1. The patient case history
2. Physical evidence to process
3. CDC Water Testing Kit
4. Blank Laboratory Report Template
5. Two copies of the Student Disease-Handbooks

Case Study:

Mrs. Polly Nomial teaches math at a local Midwestern Middle School. After teaching all day on Wednesday of last week, she went home feeling very nauseous and was having severe stomach cramps, thinking that she probably should not have used the sinks in the science lab to fill her water bottle. After a miserable night of vomiting and diarrhea, she calls in sick for work and takes herself to the emergency room. She has not even been able to keep any liquid down all night long. The doctor prescribes some medicine to help control the vomiting, but to no avail. She is admitted to the Intensive Care Unit where she remains to date. The doctors have been able to slow the diarrhea and vomiting, but Mrs. Nomial is far from being able to return home. In caring for Mrs. Polly Nomial, the doctors questioned her diet for the past week. Mrs. Nomial had spent the week-end prior to her illness camping at a local park. She commented on this being her favorite time of year to camp, because all of the young deer were easily seen. Being the "out-doorsy" type, she had tent-camped and used the local lake to freshen up, but did not use it as a drinking source.

Physical Evidence to Process:

1. Samples of water from her home, school and the lake at the camp site.

2. CDC water processing kit - instructions enclosed.

STATION 3: (salmonella)

When Teams approach this station they will encounter the following items:

1. The patient case history

2. Physical evidence to process

3. Four microscopes

4. Blank Laboratory Report Template

5. Two copies of the Student Disease-Handbooks

Case Study:

Mr. Henry Roost and his wife Ava have been in the business of raising chickens for the past twenty three years. Their farm is located in a small Midwestern town that boasts to have the largest frying pan in the country. Lately, this little town has attracted a great deal of attention as a result of an appearance in a Hollywood film. In light of this increased tourist trade, the community decided to open a restaurant, and opening night was three days ago. As a town owned and managed restaurant, the entire food inventory was supplied by members of the community, including donations from the Rooster family. Henry and his wife donated the poultry and farm-fresh eggs. The local children spent the afternoon making home-made ice-cream and Caesar Salad Dressing.

Two days following the grand opening of the restaurant, more than a dozen citizens from this town have been taken ill, one of whom has been hospitalized. This patient, Mr. Rod Bacillus is an elderly man who has recently undergone treatment for skin cancer. Although his treatment was successful and the cancer is now in remission, his immune system is still re-building itself. Mr. Bacillus is unable to keep any food or drink down as the vomiting and diarrhea worsen. His doctors are doing all they can to reduce his fever and keep him hydrated. Reports are continuing to be called in, as cases similar to those of citizens of the small town are being reported. All new cases are from people who had eaten at the newly opened restaurant. None of these patients have been admitted to the hospital as of yet.

Physical Evidence to Process:

1. Trash cans containing waste from the restaurant for the past three days.

2. Preparations of stool samples - prepared cultures mounted on microscope slides.

Collection of Artifacts:

Artifacts that are generated by the students and that can be collected for a grade during this unit include:

1. Individual fact sheets for the Student Disease-Handbooks and/or
2. Fact sheets generated by the expert group for the Student Disease Handbooks.
3. Laboratory Reports compiled by Investigative Teams during their assessment of the evidence at each of the three stations.
4. Any printed material generated as a part of student presentations given to the Director of CDC, the medical community and individuals, proprietors, land-owners, or establishments as each case dictates.

Presentation of Findings

Teams of Investigators will have one to two class periods to prepare for final presentations of their findings. Teams will address the following points:

- Disease diagnosis
- Evidence to support the diagnosis

➢Resources used to make the diagnosis

➢Assessment of risk to the community with respect to a possible outbreak

➢Recommendations to avoid the possibility of an outbreak

➢Individuals or groups to whom the recommendations are made

Teams will all share their presentations about the same case first, rather than talk about all three at one time. For all cases, the members present will include the Head of the CDC represented by the classroom teacher, and the medical team from the hospital attending to each patient, represented by other faculty members. All Investigative Teams will be given the opportunity to listen to all presentations. Investigative Teams will be given the opportunity to refute the claims made by their colleagues.

Essential to the presentations are the recommendations that Investigative Teams make. In the first case, given that the disease diagnosis is Anthrax, students need to recognize the potential threat this carries. In this instance, the Investigative Teams would need to address concerns with health and national security. By comparison, the second case describes an *E-coli* contamination, and while is poses the potential for widespread contamination, the only individuals likely to become infected, are those individuals who use the contaminated lake for recreational use. Investigative Teams should be able to make these connections and will only need to involve the land owner and local Department of Natural Resources to post the appropriate signage. The third case will require students to recognize that the Salmonella poisoning will require a thorough decontamination of the site of the source - the Roost's farm.

Collaboration:

Collaboration runs throughout this unit, beginning with the initial research and production of the Student Disease-Handbooks, continuing as the Investigative Teams work together to diagnose each of the three medical cases, and culminating with presentations. This is a difficult age to teach collaborative skills, and the idea of collaborative middle school instruction can often feel like somewhat of an oxymoron. The flip side of this same coin is the intrinsic social disposition of twelve year olds. The real challenge is finding a way to harness this energy into constructive collaboration. Having said this, this unit will take place at the end of the school year.

By this point in the year, these students will have had many opportunities to work on projects together. This unit, not being the exception, will by its very nature encourage collaboration. By creating teams of experts to generate the Student-Diseases Handbooks, groups of students will be privy to very specific knowledge. These experts will be re-distributed among the Investigative Teams, thereby forcing students to rely upon one another's knowledge and hopefully reducing power struggles within the Teams.

This unit can also take advantage of the competitive nature of middle school students to promote collaboration. The Investigative Teams will be working under time constraints while processing the evidence, assessing the symptoms of the patients in order to make a diagnosis and making recommendation to the medical community.

Summary

In Table 2 that follows all components of this unit are tabulated to summarize all five elements characteristic of problem-based learning.

Table 2:

Driving Question	Inquiry and Investigation	Artifacts	Presentations	Collaboration
As a member of the CDC, you are charged with entering a hot zone, diagnosing three unknown diseases, and making recommendations to the medical community as to how to proceed.	1. Researching diseases 2. Processing evidence in the hot zone	1. Student-Disease Handbooks 2. Laboratory Reports generated by Investigative Teams 3. Any printed material generated as a part of student presentations	Presentation of findings to Head of the CDC, the classroom teacher and the medical staff from each of the three hospitals: 1. Disease diagnosis 2. Evidence to support the diagnosis 3. Resources used to make the diagnosis 4. Assessment of risk to the community with respect to a possible outbreak 5.Recommendations to avoid the possibility of an outbreak 6. Individuals or groups to whom the recommendations are made	1. Creating the Student- Disease Handbooks 2. Working within Investigative Teams

Addendum 1:

Letter from the CDC Headquarters

Centers for Disease Control and Prevention
1600 Clifton Rd.
Atlanta, GA 30333, USA

April 15, 2010

To: Department of Infectious and Non-infectious Disease

From: Dr. Bach Teria, Director of CDC

Re: Student Disease Handbook

The Center for Disease Control and Prevention is working on compiling a Disease Handbook which can be distributed to schools across the United States. With the current events in our country, especially the Anthrax incidents, we believe it is important that all students have access to this handbook in order to become familiar with the symptoms of persons who have contracted these diseases.

We are asking that you take the attached list of diseases and research each one in order to compile an accurate description of all the information related to the disease, its symptoms, causative agent, infectivity, treatment etc. This information will be bound and disseminated to schools for use in their curriculum. This material is to be available for print by April 22nd.

Thank you for you attention to this matter.

Addendum 2:

Investigation Directions

The newly formed Investigative Teams will each receive a copy of the investigative directions to peruse on route to the scene (see Addendum 2). These directions prepare them for what they will be walking in to, including the protocol for entering the simulated biohazardous zone, a very brief description of laboratory equipment that will be available, expectations of professional conduct and the role of the teacher.

As a member of the Centers for the Disease Control and Prevention staff, you will be working on the front lines as a researcher. You will be entering a secured "hot zone" and as such will wear protective clothing including a full body Tyvek suit, goggles, booties, face mask and sterile non-latex gloves. Once inside the secured "hot zone" you will work in teams of four to examine the evidence from the three patients. This evidence will be located at three stations that will house the a description with the patients symptoms and the circumstances surrounding the onset of their illness, blood work if applicable, microscopic preparations of tissue samples if applicable, samples of physical evidence as applicable and all of the necessary laboratory supplies to process the evidence. Each station will also be supplied a Disease Handbook to use as a reference as you work.

The following procedures and requirements must be followed:

× You will have five minutes to suit up and begin working at your stations.

× Once inside, you will have 20 minutes to process the evidence at each station.

× All protective gear MUST remain on during the entire exercise to ensure your safety.

× You may ask the Director, Dr. Bach Teria, for clarifications and guidance only. Your teacher will assume this role.

×At the end of each 20 minute period, your Team will generate a written report of your assessment. This assessment will be completed on the report template located at each station. You will have an additional 20 minutes to compile your lab report. Finalized copies of these reports will be submitted to the CDC Director.

×You will have five minutes to exit the area and decontaminate by passing through the shower and then removing your protective gear and placing it in the appropriate bins.

×<u>Professional Conduct:</u>

You will be representing the Centers for the Disease Control, and as such, you will be expected to be professional at all times. Any Teams who are disruptive will be asked to leave the site and will be required to complete an alternative assignment.

Good Luck!

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