Blended Learning 6th Grade Scientific Inquiry: Design and Development Findings

Qualifying Project

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April 5, 2005

The National Center for Educational Statistics (2002) reported that, although 92.7% of students could understand basic scientific principles, only 57.9% could apply them, and a mere 10.9% could analyze procedures or data. Torp and Sage (1998) argued the problem is traditional science curricula focus on having students memorize facts rather than actively engage in authentic experiences and construct knowledge (Bybee, 2003; Hurd 1991). By "authentic experiences," the authors appear to mean offering students the opportunity to engage in real-world situations involving science. Others agree and advocate scientific inquiry reform, which views science much as scientists do, as a way of finding out why natural phenomena occur (see for example, Dunne, Loucks-Horsley, & Mundry, 2005).

The National Academy of Science (1995) suggested the most effective way to introduce inquiry is to link it to something students already know, and the National Research Council (1996) declared inquiry into authentic questions, generated from student experiences, to be the central strategy for teaching science. Today, engaging learners in science is considered the first "essential" ingredient in a widely-recognized inquiry model, known as the FiveE's (Bybee, et al., 1989), and is considered a key feature of classroom inquiry in the frequently referenced *Inquiry and the National Science Education Standards* (NRC, 1996).

Shapiro (1994) contended problem-based scientific inquiry might actively engage middle school students in more authentic learning, promote greater knowledge acquisition, and develop students' problem-solving abilities. Problem-based scientific inquiry has students investigate science by solving a problem. Savery and Duffy (1996) proposed that in order to design effective problem-based environments, the learner must "own" the problem, as well as the process. By "owning the problem," the authors appear to mean that students must be able to relate to the problem enough to take some interest in solving it.

While problem-based learning is gaining wider acceptance as a method for teaching scientific inquiry (Barrows & Myers, 1993; Evenson & Hmelo, 2000), the National Science Resource Center (1998) argued middle-school learners might gain even more from these activities if they actively engaged in designing solutions to the problems, rather than selecting solutions from those presented within the environment. Others agreed effective problem-based scientific inquiry must encourage students' self-authorship, such as designing and presenting solutions (see Baxter MaGolda, 1999 and Edelson, Gomez, & Pea, 1997). Solutions designed freely by students are often the result of "ill-structured problems," defined by Ge and Land (2004) as problems in which information and actions needed to solve the problem are not obvious.

Bersin (2003) found a blended learning approach allows corporate students to solve problems that were impossible to solve in any other way. Blended learning is a mix of online learning activities, combined with other types of delivery mechanisms, all intended to instruct. In the education sector, science reform efforts in the 1990's, which once left teachers scrambling to figure out what inquiry looked like, often focus on training teachers to teach science using an inquiry-based approach, as opposed to focusing on students (Flick, 1998).

In today's world of video games, MP3 players, movies, reality TV, the Internet and computer games, capturing the attention of students in schools is becoming increasingly difficult (Castell & Jensen, 2004). However, capturing students' attention is likely not enough. Lanham (1997) considered attention the act that converts raw data into something useful, in other words, making information meaningful. Csikszentmihalyi (1975) viewed engagement as more important than attention. He defined engagement as a balance between a challenging task and having the skills to carry out the task.

Fortunately, Jennings (1995) reported that middle school kids respond positively to participating in real-life learning tasks. Joseph (2000) advocates the "passion school" concept, which uses extreme learner interest to drive learning by encouraging active engagement with experts. This concept views learning environments as classrooms organized by communities with a common personal interest, rather than as a collection of people from the same age group. Thus, when students feel passion for a subject, they willingly invest time and energy in it.

To explore engagement with middle school science students, this study used a blended learning prototype to explore how students interacted with an ill-structured problem. More specifically, the purpose of this study was to examine sixth grade students' engagement with and responses to an authentic public health problem (the spread of the West Nile Virus), which required them to design a scientific solution.

Methodology

Research Design

For the West Nile Virus Project, I employed a single-group case study design, treating both classes as a single unit. A case study design is one of several approaches used in qualitative research, for an in-depth study of a phenomenon in its natural context, viewed from the participants' perspective (Gall, Borg, & Gall, 1996). This design is useful for providing insight into processes, as opposed to outcomes (Creswell, 2003;

Merriam, 1998). I chose this design because it allowed me to look at the processes of student engagement with and response to the inquiry, with an emphasis on students' perspectives.

Population and Sample

In order to obtain a sample, I called the principal of a Northeast suburban middle school and asked for names of teachers she thought might be willing to participate. After several more phone calls, a teacher with seven years experience volunteered to participate. During the course of her day, she taught two sixth-grade science classes with which she was willing to let me work. Ninety-eight percent of the students were U.S. Caucasian, and one was a Russian transfer student. Student ages ranged from 11-13, with a mean age of 12.0. The first class had 16 female students (57%) and 12 male students (43%). The second class had 13 female students (48%) and 14 male students (52%). With 29 female students (53%) and 26 male students (47%), the total number of students equaled 55.

At the teacher's request, students divided themselves into groups of 3-4 members each. With no further teacher intervention, the students grouped themselves into seven groups per class. The teacher commented, and I observed from my own experience as a teacher, that the higher ability groups tended to group together, as did lower ability groups.

Description of Treatment

I asked students to formulate a solution for containing the deadly West Nile Virus that had been found in their county and to design, justify, and demonstrate their solution in a final group presentation (See Appendix A for problem-solving model and Appendix

B for assignment.) The West Nile Virus Project reflected a culmination of Piagetan principles, "hands-on" manipulation, and inquiry-based science practices (NRC 1996; Papert, 1980, Piaget, 1967). The first five minutes of each class, students participated in my "show and tell," which ended by passing the shown object around the room for all to see and handle. Over a total of four weeks, during eight 45-minute classes, students spent a large portion of their time using two Web-based tools, *WISE* and *ImagiNations,* for learning facts about the disease, studying different solutions previously applied to the problem, and for visualizing microscopic samples related to the problem.

The first tool, *WISE* (http://wise.berkeley.edu) stands for Web-based Science Environment and uses design principles a number of authors advocate for scientific problem-solving and inquiry (see for example, Barrows & Myers, 1993; Evenson & Hmelo (2000); Gobert, Slotta, Pallant, Nagy, & Targum, 2002; Linn & Hsi, 2000; Savery & Duffy, 1996). Through *WISE*, students accessed information from fifteen newspaper articles about the West Nile Virus, gathered over a two-year period. I adapted the *WISE* inquiry from a previously prepared lesson on Malaria, which took approximately one month to create. In addition, I prepared and passed out personal student journals, groups folders with handouts, and a customized CD containing full-text newspaper articles.

The second tool, *ImagiNations* (http://www.lehigh.edu/~inimagin) introduced the concept of electron microscopy and allowed students access to electron micrographs for analysis. When learners visited *ImagiNations* they found an electron micrograph of a mosquito they could magnify by clicking on it. They could also view and download micrographs of the West Nile Virus, a mosquito body, and human blood cells.

In addition to classroom problem-solving activities, I encouraged teams to discuss their problem solving outside of class and through online discussion in *WISE* during the 4-week period. I also reminded students to write their daily thoughts in their journals. (See Appendix C for Journal.)

Instrumentation and Data Sources

I developed the West Nile Virus assignment and instruments, and then had them validated by two scientific inquiry researchers, one instructional design specialist, and one experienced science teacher. Howe (2001) and White (2001) suggested understanding learners' thinking processes requires direct exploration of their thoughts about how learning science in school relates to themselves and to society. To explore this, I interviewed student groups asking ten questions (Appendix D), such as, "What makes you care about learning science?" In addition to their daily journals, I also asked students to complete a five-question written survey before and after the study (Appendix E). On the last day of the problem-solving activity, I collected students' journals and had groups present their solutions by demonstrating them to the class. After the students' presentations were complete, I conducted a seven-question interview with the teacher, asking her about students' engagement with problem, creation of student solutions, and the preparation of demonstrations (See Appendix F). I also observed students and teachers over the four-week period, noting their interests, frustrations, comments, and requests of me. I also noted absences during collection of all data sources: for survey before study began (1), during interviews (2), for survey after study (0), and while completing journals (6 over 4 weeks). As a dually certified K-6 teacher and K-12 librarian, I was a facilitator, participant, observer, and researcher during the study. The teacher, along with her two aides (one per class), was a participant, an observer, and occasionally, a facilitator.

Internal and External Validity

This study used three of the six strategies that Merriam (1998) described to enhance the *internal* validity of a study: triangulation, member checks, and peer examination. For external validity, many direct quotes and detailed narrative are included, as suggested by Patton (2002).

Analyses and Associated Findings

This section is divided into two parts. Part 1 describes how I intended the prototype to function in the classroom. It includes an analysis of the data collected during the inquiry process, indicating how the prototype functioned during implementation. Part 2 describes my intentions in terms of learning design (‘learning design”), includes an analysis of the related data, and illustrates the effect the design had on the students, based on their comments and reactions.

Part I – Implementation of the Prototype

Intentions

Before the inquiry began, I thought each student would have access to his or her own computer. I expected the inquiry to operate like most typical activities involving technology. That is, once one gets past initial difficulties, the pathway is relatively smooth. I never intended to include a pretest in the inquiry, because after what I thought would be a relatively easy Group ID and password log-in exercise, I wanted students to be able to jump right into the first WISE activity. I distributed the customized West Nile Virus CD, which held copies of the full text of newspaper articles, to all groups with the intention that they could access the CD for further details or clarification of facts mentioned throughout WISE. Despite the usual glitches associated with technology lessons and log-ins, I intended the inquiry to be progressing smoothly by the end of the first class.

I also expected the inquiry to be manageable by one teacher in a classroom of approximately twenty-six students. I expected the computer lab to have a door that closed, allowing lively, collaborative discussion without distracting others. In addition, because I was careful to address state and national standards for scientific inquiry, I intended the inquiry to be integrated into the regular.

Data Analysis

Observational data, along with student, teacher, and aide comments and reactions, provided information about operational, technical, managerial, class staffing and curricular issues. I analyzed and interpreted the data from my perspective as an experienced teacher, comparing how I intended the project to function to the reality of how it actually functioned in the classroom.

Findings

During the first two days, the operational and technological aspects of the inquiry did not function as originally planned. An automatic pretest (built into WISE) appeared to my surprise and confused the students. The group ID/password log-in exercise was confusing as well and took more time than I anticipated. In this case, each student had his or her own computer, so it worked out better to have each student log on individually and work offline in their group. Beyond the group issue, there was a fair amount of trouble logging onto WISE once the individual IDs and passwords were established. This happened for four reasons: 1) bandwidth was at its most limited at the time the lesson was being accessed; 2) students had to create two IDs and passwords (one for the district as well); 3) all students trying to access the same location at the same time overloaded the WISE server and computers hung up; and 4) students continually forgot their two IDs and passwords, and URLs. Despite the careful preparation of the newspaper articles CD, students discovered it wouldn't appear as an icon on the school computer desktops because of district restrictions on downloading information, which made all the CDs useless. Despite my belief that the inquiry was manageable by one teacher, many operational, technical, and task-related questions kept the teacher, an aide, and me continuously busy.

The room where the study took place was designed with a 1960s "open classroom" concept, which means it was built without a door and inner walls. Hence, the computer lab was located in an open mezzanine just above the library and collaborative discussions caused a higher-than-normal noise level that sometimes distracted others. Despite my intention to have the inquiry adopted into the curriculum as a regular, repeatable activity, it was used as an enhancement activity.

Part 2 - Learning Design

Intentions

I designed the inquiry around a community problem, which I thought the students would relate to. While designing, I used phrases like, " YOU ARE A SCIENTIST TOO, WITH FRESH IDEAS!" which I hoped would prompt students to think of themselves as scientists. The design encouraged ownership of team identity and teamwork by allowing students to group themselves and choose their own names. I encouraged the students think creatively by allowing them to choose their own design method and medium for both their solution and their demonstration. By using a shared foundation of resources, I thought students would discuss the same material and collaborate more easily with one another. Being part of a scientific research community at a nearby university, I was able to include references to “cutting-edge” research about nanotechnology in the students’ shared materials, to foster curiosity. Since the nanotechnology information offered to the students was so “cutting-edge,” I intended our student scientists to think they had special knowledge not yet available to the general public. This also cultivated a connection with the university scientists working on the same kinds of problems the sixth-graders were. As a final incentive to engage students, I discussed the brand new ‘aberration-corrected” microscope which was just assembled at the university to explore the nano world on the atomic scale. Through the ImagiNations Website, I included images generated from an environmental scanning electron microscope (ESEM) located at the university, that related to their problem and potentially their solutions. This was to impress upon students that they had access to the same kinds of tools that scientists use to visualize microscopic samples for solving problems.

Data Analysis

The students’ responses written before and after the study, along with their journal entries, comments, and interview responses provided information about the learning design and its effect on their engagement with the inquiry. I analyzed the data by coding the variables and putting them into categories I constructed, as suggested by Merriam (1998). I constructed or derived the categories from broader themes that emerged from the variables, as suggested by Maxwell (1996). Over a three-month period, my colleague and co-author helped me collapse the variables through a rigorous data-reduction scheme, which also reduced the number of categories. After the final reduction, seven categories remained, which represented two main themes. The two main themes, which emerged from the analysis of the data, were "*student relevance*" and "*student investment*." Both themes reflect students' engagement with the problem. The following section describes how each category was constructed from the variables.

Findings

As Table 1 indicates, we constructed seven categories from the variables.

Table 1 Constructed Categories

1. Personal Relevance
2. Importance of the Problem
3. Value of the Solution
4. Value of Deriving the Solution
5. Interest or Positive Attitude
6. Student Investment of Feelings and Emotions
7. Student Investment of Time and Energy

Category 1, Personal Relevance, was derived from student references to how the problem of the West Nile Virus affects them, their family members, and where they live. Category 2, Importance of the Problem, was derived from student comments, that suggested they understood the seriousness of the problem, with people getting sick or dying. Category 3, Value of the Solution, represented student references to their solutions as helpful in saving lives and/or preventing West Nile Virus. Students' comments and reactions placed into Category 4 (Value of Deriving Solution) indicated students felt they had the ability to make a difference in, or a contribution to, stopping or slowing the spread of West Nile Virus. This category also often included student references to the importance of the solution outside of the classroom; for example, to the community and scientists. Examples of the types of data used in constructing the first four categories are shown in Table 2.

Table 2 Illustrating Students' Active Responses to the Learning Task

Category	Written student data	Oral student data
Value of Deriving Solution (Making a difference, contributing to scientific knowledge, scientists and people in community could be helped by solution)	"We had a chance to solve a worldwide problem." "I'm proud," "I feel important to be helping to solve a problem for a big situation," "I'm included in doing something good for my community and country," "to help scientists," "discussed ideas like presidents and governors – wicked discussions," "that we are trying to help scientists," "makes other people know kids are thinking,," "that we could make a difference," "scientists see the video – they could use our resource" "Shows people what we did and what we think"	"maybe scientists will listen to our solutions and it will help solve the problem" "scientists may know about it" <students' ideas> "What if solution doesn't exist in real life?" "because we are doing something good for our community"
Value of Solution Itself (Saving people)	"I save a lot of people," "that someone tries our solution and it helps"	"it could save lives if we can prevent it" "people will die if we don't find a solution"
Importance of Problem (People are getting sick and dying)	"the president could get sick,""this is serious" "if a kids dies that's really sad"	"See, there's like innocent people in this world and they haven't done anything and they could get the disease and stuff"
Personal Relevance (Students use words indicating they are gaining information not known previously to them or their families) (How problem affects family members and self, and where they live)	"we learned a lot," "learning stuff I never knew," "that we learn from it" "People who are wonderful that die from WNV and my family so that they may be healthy and safe," "I wouldn't want to get infected by it and if I'm already I would want to find a cure" "My family and friends could get the WNV and they could be sick or even die" "I didn't know the West Nile Virus was in the Lehigh Valley." "I didn't know it was at the Game Preserve."	"Learning something that none of my family members knew." "Can older people get the West Nile Virus?" <said in a worried tone> "Useful for hunters." <this suburban district also contains a rural area where some students and parents hunt>

Category 5, Interest or Positive Attitude, was derived from students' actions and comments indicating they were excited, motivated, focused and eager to learn about new topics and be involved in the task. Category 6, Student Investment of Feelings and Emotions, was constructed to contain *more emphatic* student comments and actions about the topic and the task. These comments indicated they were absorbed in problem solving and were willing to invest feelings in it; (for example, "I love…," "I hate….")
This category was also derived from teacher comments, such as, "they loved that," suggesting that the teacher perceived students as emotionally engaged with scientific topic.

The final category, Student Investment of Time and Energy, was constructed to encompass student comments indicating their desire to take on additional work in science, anticipating they would have more confidence in future performances. This category was derived from student actions indicating they were willing to invest more than just class time in the assignment, as well as willing to give up free time to complete the assignment, both in school and out of school (a sacrifice for science, so to speak). Additionally, this category encompasses teacher comments that reveal students investment of extra time and energy to work on task outside of school, and students' taking interest in science home to their parents. Some student comments and reactions placed in Category 7 reflect the notion suggested by Cates and Bishop (2003) that successful engagement in inquiry charges learners with enthusiasm and energy for future performances. Categories 5 through 7 are shown in Table 3.

Table 3 Illustrating Students' Investments in and Emotional Reactions to the task

Category	Observations	Written student data	Oral student data	Teacher interview data
Student Investment of Time and Energy, Desire for Another Run (Cates and Bishop, 2202-2003)	Students spontaneously, without prompting, described work or progress to me as I walked around the room. Several groups asked the teacher if they could come back during activity period to work on their presentations. <students want to work overtime>. Two groups discussed planning to meet at students' houses on weekend to work on solution demonstration.	"People will like science more now because they will have more confidence that they can do better, if they do well on the West Nile Virus Project." <willingness to make future investment>	"Do you want to meet at my house to work on the video? Call me." <Group solution demonstration was in the form of a video.>	"One group, the one with the news show, they had been up here every single day at recess, practicing, practicing, practicing, working on their poster every free second they got so …yeah, they knew what they were doing." "I think they learned a lot and they were very excited about it and a couple of parents at the conference actually talked about it that the kids were working on it at home a lot and were motivated by it." <This was an ungraded assignment.> " Kids asked for passes for lunch recess and gave up their recesses for a couple of recesses to come up and practice and work on posters and stuff like that." "A lot of the kids went back and looked at the pictures, they showed their parents the pictures, so yeah." <students invested time outside of school>
Student Investment of Feelings, Emotions	One girl gets upset that her online comment is accidentally submitted before she completes her thought. Students are cooperative but bashful about answering interview questions	"I *hate* all mosquitoes!" "If you have a dead bird in your yard, get rid of it, those stinky dead birds have the virus!!!!!"	"I *love* science," "amazing," <said with heartfelt emotion> "You are stealing my solution!" "We believe in our solution."	"They loved that." "It was cool and they loved it." <referring to the daily 5 minute nanotechnology introduction>
Interest or Positive Attitude (focus toward topic or task)	Students eagerly tell one another their solutions, talking fast, interrupting each other, using hands to describe ideas, discussion is big and noisy, but mostly about topic, one group finds outside sources to support their solution. Students frantically put information into online comments. Student quietly reprimands another during interview when one starts goofing off while others are talking.	"Go to the West Nile Becomes a Fact of Life to go to the deet site, it rocks!" "We have two solutions so far." <appearing to suggest that more are coming, when only one was required>	"ouuu," "interesting," "Cool," "Listen to this" <response to WNV information online>	they were excited, motivated, eager to learn," "no pressure, they could just be creative …liked the freedom," " "you could physically read their body language, even when we just said, you know, time to go to the computer lab, they got excited"

During the final presentations, students' solutions were creative, but despite my intentions to encourage students' use of electron micrographs for problem analysis and/or solution demonstrations, only one group used them for analysis and none for demonstration.

Discussion

Based on my prior experiences as a classroom teacher, I would consider this inquiry a successful activity. I was pleasantly surprised by how well the prototype worked in the classroom. While I had high expectations for the operational and technical aspects of the lesson, and there were a fair number of operational and technical issues, they did not appear to defeat the purpose of the learning design. In contrast, while I had some expectations students might exhibit a sense of engagement with the problem and solution process, the findings suggest higher levels of student engagement than I had anticipated.

During students' initial group discussions, they assigned themselves intellectually affirmative names (The Smarties) and task-related names (The Bat Flyers). These group names indicated to me that, as collaborators, students considered themselves capable of solving the problem and related to the problem, if only superficially. Student collaboration was an important component to the process and outcome of the inquiry. In fact, according to student response, collaboration was the <u>most</u> helpful aspect of problem solving. We observed evidence of this: students discussing tasks excitedly, sharing resources, thinking aloud, "one-upping" each other with new solutions, finishing each other's sentences, and requesting specific artifacts to help demonstrate their solutions. The design feature that appears to have helped contribute to this finding was the use of a shared foundation of student resources during problem-solving, which allowed students to analyze the same set of facts from their different perspectives.

According to Chapman (2003), behavioral criteria indicate the extent to which students make active responses to the learning task. In this study, it appears the students' sense of the relevance of the problem evolved on several levels, beginning with " I wouldn't want to get infected with it," and culminating with " having a chance to solve a worldwide problem." The range of these comments seems to indicate what we are looking at is a hierarchy from a lower-level sense of personal relevance to a much higher-level sense of relevance to the world outside the classroom. (see Figure 4).

As the students learned facts, such as, a baby in the womb could get West Nile Virus and that the bald eagle at their local game preserve (which many of them knew from previous field trips) died from West Nile Virus recently, it appears they began relating to the problem with such intensity that they gained a sense of purpose for their inquiry. For these students, it became highly relevant to design a solution, and as a result, their solution took on more importance. As the importance of their solution increased, it seems the sense of their own importance increased to a perception of empowerment. It seems that students who reach the highest perception of empowerment value their solution because they believe they are able to make a difference, by helping scientists and other people in the community and beyond. These students felt "important," " like presidents and governors," and believed that "scientists could use their resource," all strong indicators of genuine student empowerment. Students began to think of themselves as capable of helping scientists, and as being part of the real scientific team working on the problem. The supportive phrases designed to encourage the students throughout the inquiry seem to have contributed to their perception of empowerment as well. Thus, we hypothesize, learning scientific facts engages students when those facts relate to a real purpose. A problem that is real, local and relevant appears to provide that purpose. If students are also encouraged to believe they are capable of contributing to the solution of the problem (their purpose), we conclude they will engage with the inquiry.

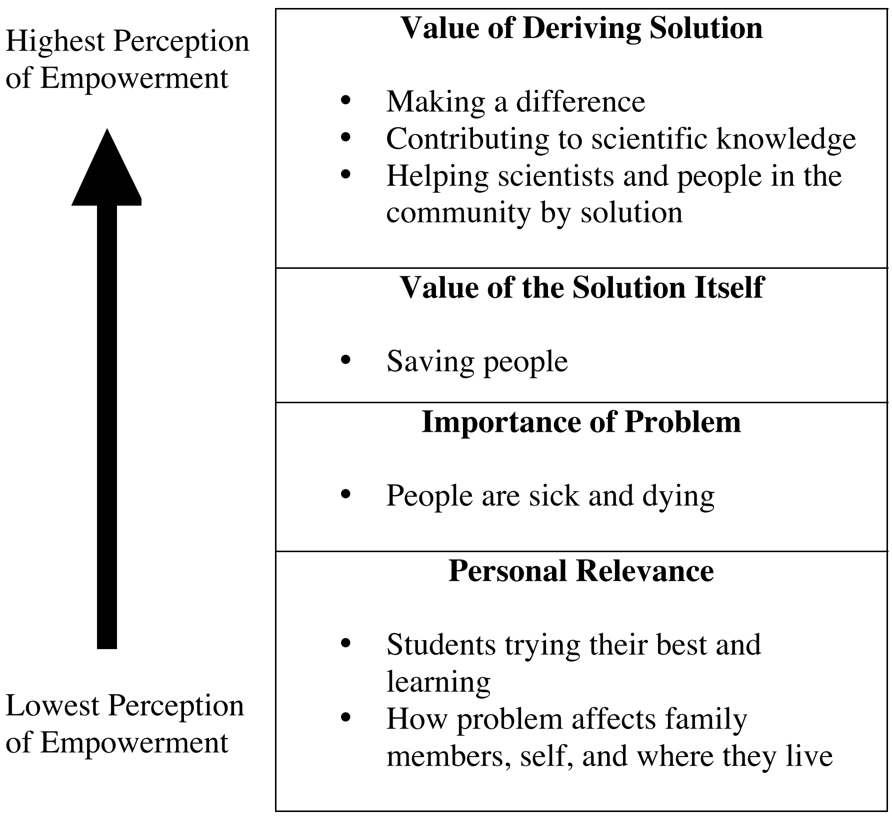

Figure 1. Criteria for Hierarchy of Empowerment in Behavoiral Domain. Categorizes the active responses students attributed to the task and illustrates how the perception of empowerment builds from the lowest level of personal relevance to the highest level value of deriving the solution.

Additionally, student comments referring to the transfer of their new knowledge from the classroom to the university to the community seem to indicate the design features, such as students' indirect connection with scientists at the university (through my visits) and the cutting-edge nature of the research, are important factors contributing to the students' sense of empowerment. There was little, but some indication that access to scientists' tools contributed to the students' sense of empowerment. However, one student did respond," If I hadn't seen the picture, I wouldn't have gotten the idea," which seems to show that visualization of the micrograph may have engaged him by stimulating his thought process during the inquiry.

Affective criteria indicate the level of students' investment in and emotional reactions to the learning task, as well as their interest or positive attitude (Chapman, 2003). During the inquiry, it appears what began with a positive attitude toward the task ("Go to the deet site; it rocks!") evolved into students' more intense investment in the task (" Do you want to meet at my house [this weekend] to work on the video?")[their solution demonstration]). Additionally, the teacher comment that students were using "every free second" on their demonstration preparation indicates that students were investing nearly all their free time in the inquiry. We interpret this to mean that students who are willing to invest a noticeably large amount of time to the task are exhibiting a substantially high level of interest in the inquiry.

The range of the student comments, along with their actions, seem to indicate that what we are looking at is a hierarchy from a lower-level sense of interest and investment to a much higher-level of interest, which includes investment of emotion, time, and energy outside of the classroom (see Figure 2). It appears the students who reach the highest level of investment grow passionate about completing their solutions. This passion again appears to be stimulated by designing around an authentic and relevant problem, and the students' desire to help. I was pleasantly surprised and impressed by the sixth-graders' passion and determination to help others.

Other factors that contributed to the students' sense of passion may have been the ill-structured nature of the problem. The learning design allowed students to design their solutions in any way that used at least three facts, and they were free to use their choice of medium, such as a poster or video, for their demonstration. It is important to note that the teacher chose this as an ungraded assignment, which may have also enhanced the students' perception of freedom for creativity without consequence.

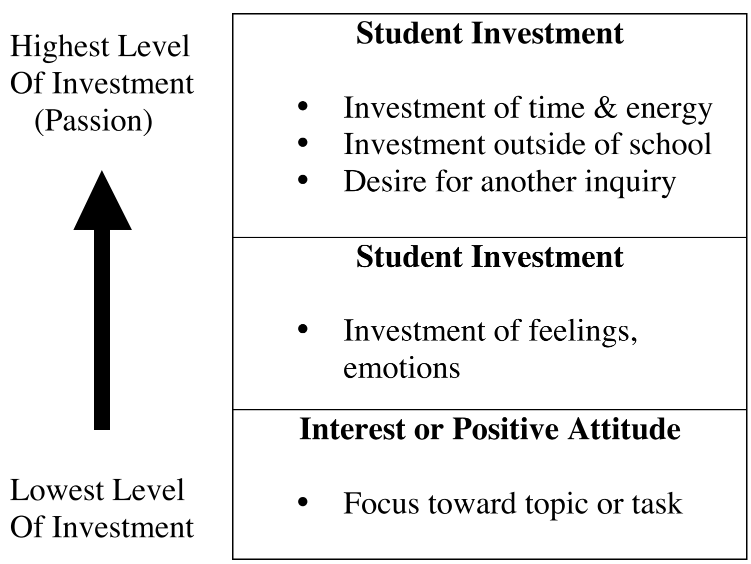

Figure 2. Criteria for Heirarchy of Passion for Science in Affective Domain. Categorizes the levels of students' interest, investment in and emotional reactions to the learning task. The hierarchy illustrates how this sense of passion for science builds from the lowest level of investment, a positive attitude, to the highest level, indicated by

increased confidence in scientific problem-solving and the desire for "another run." (Cates & Bishop, 2003).

As noted earlier, many educators and researchers agree problem authenticity and relevancy, as well as having students design solutions, are important factors for engaging students in scientific inquiry. Findings from this study seem to confirm this. However, additional learning design elements, which encourage empowerment, passion and freedom of expression should not be overlooked, and may well be as important as inquiry features already accepted as effective. In addition, university relationships, which foster involvement with cutting-edge research and instrumentation may prove effective "attention getters," for student engagement. Although this study intended students to use micrographs generated from the scientists' electron microscope, surprisingly, this did not happen. This indicates that the use of the microscopy was not designed in such a way that students found useful or engaging. The images did appear to interest them, but were seldom mentioned. This suggests that students' exposure to the electron microscope's capabilities was not compelling enough on its own, and that use of electron microscopy with middle school students during inquiry requires more thoughtful design.

Future Directions

This study offered useful insights, but some questions still remain. For example, how can we design the use of electron microscopy to make it more functional and engage learners? How might scientists become more involved to facilitate learning? Given the time that this inquiry took to develop, which is more than a teacher might have, how can we facilitate easier development and implementation of scientific inquiry in middle schools? This study looked at inquiry process, but not at product or outcome. Thus, what effect does this blended learning design have on student comprehension, achievement, and life-long inquiry? These and related questions form a strong foundation for future research.

References

Barrows, H.S., & Feltovich, P.J. (1987). The clinical reasoning process. *Medical Education, 21*, 86-91.

Barrows, H.S., & Myers, A.C. (1993). *Problem-based learning in secondary schools.* Unpublished manuscript. Springfield, IL: Problem-Based Learning Institute, Lanphier High School, and Southern Illinois University Medical School.

Baxter Magolda, M.B. (1999). *Creating contexts for learning and self-authorship: Constructive-developmental pedagogy*. Nashville, TN :Vanderbilt University.

Bersin, J. (2003). What works in blended learning. *Learning Circuits*. Retrieved March 13, 2005 from http://learningcircuits.org/2003/jul2003/bersin.htm

Bybee, R.W., et al. (1989). *Science and technology education for the elementary years: Frameworks for curriculum and instruction.* Washington, D.C.: National Center for Improving Instruction.

Bybee, R. W. (2003). *Science curriculum reform in the United States.* Washington, DC: National Academy of Sciences. Retrieved May 5, 2003, from http://www.nas.edu/rise/backg3a.htm

Castell, S., & Jenson, J. (2004). Paying attention to attention: New economies for learning. *Educational Theory*, *54*, 381-397.

Cates, W.M., & Bishop, M.J. (2002-2003). Learner as bobsled operator: The physics of learner engagement. *Journal of Educational Technology Systems*, *31*, 291-305.

Chapman, E. (2003). Alternative approaches to assessing student engagement rates.

Csikszentmihalyi, M. (1975). *Beyond Boredom and Anxiety: Experiencing Flow in Work and Play*. San Francisco: Jossey-Bass Publishers.

Practical Assessment, Research, & Evaluation. Retrieved November 1, 2004 from http://pareonline.net/getvn.asp?v=8&n=13

Creswell, J. W. (2003). *Research design: Qualitative, quantitative and mixed methods approaches*. Thousand Oaks, CA: Sage.

Dunne, K., Loucks-Horsley, S., & Mundry, S. (1998). Inquiry is a "hands-on" and "minds-on" experience for both students and teachers: An interactive Q&A with experts on professional development for science teachers (Science Education Reform Dialogue). *Harvard Education Letter*. Retrieved January 5, 2005 from http://www.edletter.org/past/issues/1998-so/rf-dialogue.shtml

Edelson, D.C., Pea, R.D., & Gomez, L. (1997). Constructivism in the collaboratory. In B.G.Wilson (Ed.), *Constructivist learning environments: Case studies in instructional design* (pp. 151-164). Englewood Cliffs, NJ: Educational Technology.

Evensen, D.H., & Hmelo, C.E. (2000). *Problem-based learning: a research perspective on learning interactions*. Mahwah, NJ: Lawrence Erlbaum.

Flick, L. B. (1998). *Integrating elements of inquiry into the flow of middle level teaching*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching Annual Meeting. San Diego, CA.

Gall, M.D., Borg, W.R., & Gall, J.P. (1996). *Educational research: An introduction.* White Plains, NY: Longman.

Ge, X., & Land, S.M. (2004). A conceptual framework for scaffolding ill-structured problem-solving processes using question prompts and peer interactions. *Educational Technology Research & Development*, *52(*2), 5-22.

Gobert, J., Slotta, J., Pallant, A., Nagy, S., & Targum, E. (2002). *A WISE inquiry project for students' east-west coast collaboration.* American Educational Research Association Inquiry Paper. Retrieved March 26, 2003, from http://mtv.concord.org/publications/online_learning.pdf

Goldhaber, M.H. (1998). The attention economy will change everything. *Telepolis*. Retrieved March 21, 2005 from http://www.heise.de/tp/r4/artikel/1/1419/1.html

Herrington, J., Oliver, R., & Reeves, T.C. (2003). Patterns of engagement in authentic online learning environments. *Australian Journal of Educational Technology*, *19*, 59-71. Retrieved November 11, 2004, from http://www.ascilite.org.au/ajet/ajet19/herrington.html

Howe, K.R. (2001). Qualitative educational research: The philosophical issues. In *Handbook of research on teaching* (4th ed., pp. 201-208). Washington, DC: American Educational Research Association.

Hurd, P.D. (1991). Why we must transform science education. *Educational Leadership, 49*, 33-35.

ImagiNations (2001). What is electron microscopy? Retrieved February 28, 2005 from http://www.lehigh.edu/%7Einimagin/whatisem.html

Jennings, J.F. (1995). School reform based on what is taught and learned. Retrieved September 10, 2004 from http://www.ctredpol.org/pubs/reform.html

Joseph, D.M. (2002). Passion as a driver for learning: A framework for the design of interest-centered curricula. Seattle, WA: John G. Nicholls Trust. Retrieved February 28, 2005 from http://tigger.uic.edu/~thork/Trust/joseph.htm

Lanham, R.A. (1997). The economies of attention. *Michigan Quarterly Review*, *36*, 270-284.

Lankshear, C., & Knobel, M. (2002). Do we have your attention? New literacies, digital technologies and the education of adolescents. In D. Alvermann (Ed.), *New Literacies and Digital Technologies: A Focus on Adolescent Learners*. New York: Peter Lang. Retrieved March 21, 2005 from http://www.geocities.com/c.lankshear/attention.html

Linn, M.C., & Hsi, S. (2000). *Computers, teachers, peers: Science learning partners.* Hillsdale, NJ: Erlbaum.

Maxwell, J.A. (1996). *Qualitative research design: An interactive approach*. Thousand Oaks, CA: Sage.

Merriam, S. B. (1998). *Qualitative research and case study applications in education.* San Francisco, CA: Jossey-Bass.

National Academy of Sciences (1995). National science education standards (draft). Washington, D.C.: National Academy Press.

National Center Educational Statistics (2002). *Percent of student at or above selected science proficiency levels by sex, race/ethnicity, control of school, and age:1977 to 1999*. Retrieved March 25, 2003, from http://www.nces.ed.gov/pubs2002/digest2001/tables/dt131.asp

National Resource Council (1996). *National science education standards*. Washington: DC: National Academy Press.

National Science Resource Center (1998). *Resources for teaching middle school science*. Washington, DC: National Academy. Retrieved March 26, 2003, from http://books.nap.edu/books/0309057817/html/R3.html#pagetop

Patton, M. Q. (2002). *Qualitative research & evaluation methods*. Thousand Oaks, CA: Sage.

Piaget, J., & Inhelder, B. (1967). The coordination of perspectives. *In the child's concept of space* (pp. 209-246). New York: Norton.

Papert, S. (1980). *Mindstorms*. New York, NY: Basic Books.

Rideout, V., Roberts, D.F., & Foehr, U.G. (2005). Executive summary: Generation M: Media in the lives of 8-18 year-olds. Menlo, CA: Kaiser Family Foundation. Retrieved March 15, 2005 from http://www.kff.org/entmedia/7250.cfm

Savery, J.R., & Duffy, T.M. (1996). Problem-based learning: An instructional model and its constructivist framework. *Educational Technology, 35*, 31-38.

Shapiro, B.L. (1994). *What children bring to light: A constructivist perspective on children's learning in science*. New York: Teachers College.

Torp, L., & Sage, S. (1998). *Problems as possibilities*. Alexandria,VA: Association for Supervision and Curriculum Development.

Web-based Inquiry Science Environment -WISE (2000). Pine Creek *Project Profile*. Retrieved April 10, 2003, from http://scale.soe.berkeley.edu:8080/scale/projects/curriculum/profiles/WISE_Profile.pdf.

White, R. (2001). The revolution in research on science teaching. In *handbook of research on teaching* (4^{th} ed., pp. 457-471). Washington, DC: American Educational Research Association.

Appendix A: Barrows and Myers' Model

STARTING A NEW CLASS

1. **Introductions**
2. **Climate Setting** (including teacher / tutor role)

STARTING A NEW PROBLEM

1. **Set the problem.**
2. **Bring the problem home** (students internalize problem)
3. **Describe the product / performance required**
4. **Assign tasks** (Scribe 1 at the board, Scribe 2 copying from the board, and reference person)

IDEAS (Hypotheses)	FACTS	LEARNING ISSUES	ACTION PLAN
Students' conjectures regarding the problem--may involve causation, effect, possible resolutions, etc	A growing synthesis of information obtained through inquiry, important to the hypotheses generated	Students' list of what they need to know or understand in order to complete the problem task	Things that need to be done in order to complete the problem task

5. **Reasoning through the problem**

What you do with the columns on the board

IDEAS (Hypotheses)	FACTS	LEARNING ISSUES	ACTION PLAN
Expand / focus	Synthesize & re-synthesize	Identify / justify	Formulate plan

6. **Commitment as to probable outcome** (although much may need to be learned)
7. **Learning issue shaping/assignment**
8. **Resource identification**
9. **Schedule follow-up**

PROBLEM FOLLOW-UP

1. **Resources used and their critique**
2. **Reassess the problem**

What you do with the columns on the board

IDEAS (Hypotheses)	FACTS	LEARNING ISSUES	ACTION PLAN
Revise	Apply new knowledge and re-synthesize	Identify new (if necessary)	Redesign decisions

PERFORMANCE PRESENTATION

AFTER CONCLUSION OF PROBLEM

1. **Knowledge abstraction and summary** (develop definitions, diagrams, lists, concepts, abstractions, principles)
2. **Self-evaluation** (followed by comments from the group)
   - Reasoning through the problem
   - Digging out information using good resources
   - Assisting the group with its tasks
   - Gaining or refining knowledge

Note. From *Problem-based learning in secondary schools*. Unpublished manuscript by H.S. Barrows and A.C. Myers, 1993, Springfield, IL: Problem-Based Learning Institute, Lanphier High School, and Southern Illinois University Medical School. Copyright 1993.

Appendix B: The West Nile Virus Problem Solving Assignment

Welcome to the

West Nile Virus Project

Have you ever heard of a disease called the West Nile Virus? Did you know that it is a growing local health problem in Pennsylvania, New York, and New Jersey? In fact, the virus was detected in the Western Hemisphere for the first time in New York City in 1999 and by 2000, the first case of West Nile Virus appeared in Pennsylvania.

By 2002, Pennsylvania recorded 59 human cases, and eight deaths. Birds and mosquitoes are spreading the disease. It has been found in 21 of Pennsylvania's 67 counties, including Lehigh County. The virus causes inflammation of the brain. Doctors and scientists have not figured out a good way to control this deadly disease. The good news is that most people infected with the virus never get sick, or they get only mild symptoms, like a headache and low fever. People with weakened immune systems are more at risk, so wash your hands frequently, wear long pants and long sleeve shirts outside, especially in early morning and evening, use bug repellent with DEET, and stay healthy!

In this project, you will learn all about the West Nile Virus: where it is found, how it spreads, and what can be done to prevent it. You will also learn that there are different approaches to controlling the West Nile Virus, and you will be asked to figure out your approach to controlling this new and spreading virus.

Many scientists disagree about which method is best. You will have a chance to weigh the evidence and decide for yourself which method is most effective, or invent a completely new method! First you and your group members should determine what you think might be the best way to control this disease – this will be your hypothesis. Next you should all decide what you need to do to test your hypothesis and who will be responsible for each task. Then you should begin your exploration of the evidence – finding lots of facts! After you examine all the evidence and dig out what you think you need, you should reason through the problem and decide on a solution based on your scientific evidence. You should discuss all your findings and ideas with your group partners. As a group, you should reassess the solution and commit to a group solution, based on all the evidence. Your group's justification and explanation for choosing that solution will be presented to the class in a final presentation, which should include facts to back up your solution and may include visual aids.

Good luck future scientists – we need your help!
Signed, the community

Appendix C: Student Journal Entry

Journal Entry –Please circle correct Day of Activity 1 2 3 4 5 6 7

1) I liked or disliked trying to solve this problem today because…

2) I think it is most important that …

3) Today, during our scientific problem solving,

____

____ went well and

____

____went badly.

4) My group's most recent solution …

5) Today, my group …

Appendix D: Student Interview Questions

Ownership of Problem and Solution Process:

1) Do you care about learning science?

2) What makes you care about learning science?

Construction of Artifacts:

3) Do you care about creating your own artifacts while learning science?

4) What makes you care about creating your own artifacts?

5) Do you think creating your own artifacts helps you to solve a problem?
Follow-up: Why?

Collaborative Scientific Inquiry Process:

6) How do you feel about using the scientific process to solve a problem?

7) Do you think it is important to collaborate with others during scientific problem solving?

8) Why do you think your group's solution will work to solve the problem?

Communicating and Justifying Explanations to Others:

9) Do you care about presenting your solution to the rest of the class?

10) Why do you care about presenting your solution to the class?

Appendix E: Before-study and After-study Survey

Before-study

1) What makes you care about helping to solve the spread of the West Nile Virus?

2) Do you think sharing resources on the Web will help your group come up with a good solution to the problem of the West Nile Virus, and why?

3) Do you think it is important to work with others during scientific problem solving, and why?

4) Do you think that making a visual demonstration of your solution will help you to solve the problem, and why?

After-study

1) What made you care THE MOST about helping to solve the problem of the spread of the West Nile Virus?

2) Which of the materials used in this class helped your group THE MOST (including your own) to solve the problem of the spreading West Nile Virus?

3) What was MOST IMPORTANT about working with others during scientific problem solving?

4) What was it about making a visual demonstration of your solution that helped THE MOST in solving the problem?

Appendix F: Teacher Interview Questions

The teacher was asked to, "Please respond to the following questions or statements," concerning the topics highlighted below:

Ownership of Problem and Solution Process:

1) How did the students feel about this project?

2) What makes you think that?

Construction of Resources:

3) Do you think the students care about making their artifacts during problem solving?
   Follow-up: Why?

Scientific Inquiry Process

4) Do you think the students cared about using the scientific process to reason through this problem?

5) Do you think the student collaboration was important?
   Follow-up: Why?

Communicating and Justifying Explanations to Others

6) Do you think the students generally came away with an understanding of the problem and possible solutions?

7) Do you think they were able to communicate this effectively using their artifacts?