Modeling Metacognitive Strategies for Student Adoption within a Problem-Based Learning Unit

Lynn E. Panton
St. John Fisher College

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Modeling Metacognitive Strategies for
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Advisor

Faculty Reader

Faculty Reader

Faculty Reader

Peer Reviewer

GMST Program Director
Table of Appendices

Appendix A: Class Test Scores .................................................................... page 69

Appendix B: Unit of Study Lesson Plans ....................................................... page 70

Appendix C: Request For Proposal ................................................................. page 88

Appendix D: Focus Questions ....................................................................... page 89

Appendix E: Problem Log Reflective Questions ........................................... page 90

Appendix F: Problem Log Rubric ................................................................. page 91

Appendix G: Preparing Your Presentation .................................................... page 92

Appendix H: Presentation Rubric ................................................................. page 93

Appendix I: Think Back – Summative Reflection ......................................... page 94

Appendix J: Designing a Playground ............................................................. page 95
Table of Tables and Figures

Table 1: Need to Know Board .................................................... page 28

Table 2: Student Example: Need to Know Board ....................... page 43

Table 3: Prioritized Learning Issues List .................................... page 54

Figure 1: Student Sample – Mind Map ...................................... page 45
Much has been written about problem-based learning and its ability to promote metacognition and self-directed learning. (Sage and Torp, 1998) This study was designed to determine if teacher modeling of metacognitive strategies, within a problem-based learning unit, would help students become independent, reflective thinkers. Metacognitive strategies modeled were the need-to-know-board, mind mapping, and reflective writing in daily problem logs.

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MODELING METACOGNITIVE STRATEGIES FOR STUDENT ADOPTION WITHIN A PROBLEM-BASED LEARNING UNIT

Part One: Purpose of Study

As I developed my final paper for my MS in Mathematics, Science, and Technology Education degree I took the time to go back and read my personal mission statement which I developed during my first class. As part of my vision I wrote:

"I walked among my students – observing, commenting, questioning. The students are scattered throughout the room, engaged in different pursuits. One student is working at a computer surfing the Internet for information on environmentally safe cleaning supplies. The results of his research will be part of next week's Green Fair being held at the Community Center. Another student returns from the greenhouse with a master gardener. The student announces they have determined the square footage for the new vegetable garden. They have also predicted the percentage yield from the new seeds they have planted....Through the doorway I watch a team of students discussing animal care with a
group of visiting preschoolers. They have been working on an embryology project and have newly hatched ducks to show the children.

At the time I wrote my mission statement I did not have the vocabulary to describe what I wanted for my students but now I do. I was describing self-directed learners. Even if I had known the vocabulary at that time, I had no idea how to help my students become active, independent learners in control of their own learning.

As I progressed through my graduate courses I was introduced to numerous strategies for helping students move to higher levels of thinking. I learned about inquiry-based learning; MST project centered learning and creative problem solving.

In October 1999, I attended a two-day seminar presented by Dr. William Stepien and Dr. Sheila Gallagher, leading proponents of problem-based learning. At the completion of this workshop I knew I had found a way to help my students take control of their own learning. I continued my research into problem-based learning by completing an independent study on problem-based learning, attending more workshops and talking with colleagues interested in problem-based learning. As I became both more familiar with and committed to problem-based learning, I kept asking one nagging question — how do I take students who are used to direct instruction, students who demand “just tell me the answer” and get them to think independently? How do I get them to develop their own questions? All my
research indicated problem-based learning would help me do this. I hypothesized that problem-based learning should help students become independent, reflective thinkers.

My interest in helping my students become self-directed learners had clearly led me to problem-based learning. As I combed the research literature I found myself trying to construct my own meaning of two interrelated topics, metacognition and problem-based learning. The literature showed the interdependence of these two concepts. I needed to understand how the two concepts intertwined to help students develop into self-directed learners. Finally I knew the only way to understand this relationship was to work through the problem-based learning process with a group of students.

Purpose

The purpose of my study was to determine if teacher modeling of metacognitive strategies, within a problem-based learning unit, would help students become independent, reflective thinkers. I tried to answer this by focusing on three questions.

Research Question One: As a problem-based learning coach, does modeling of metacognitive strategies help students adopt these strategies as they try to solve ill-structured problems?

Research Question Two: Is there growth in the way students talk about their ability to problem solve?

Research Question Three: Do these metacognitive strategies help students acquire content knowledge?
Part Two: Theoretical Framework and Literature Review

Introduction

Much has been written about problem-based learning and its ability to "promote metacognition and self-regulated learning." (Sage & Torp, 1998, p.23) Through this literature review I will document the characteristics of problem-based learning and its relevance to the K-12 educational system. Then I will describe the interrelationship of problem-based learning and metacognition. Finally I will describe three accepted metacognitive strategies that help students direct their own learning while attempting to solve ill-structured problems.

Characteristics of Problem-Based Learning

Torp and Sage state that "problem-based learning is focused, experiential learning organized around the investigation and resolution of messy, real world problems. It is both a curriculum organizer and instructional strategy, two complementary processes." (Sage & Torp, p. 14) "Three features set the parameters of problem-based learning: initiating learning with a problem; exclusive use of ill-structured problems; and using the instructor as a metacognitive coach." (Gallagher, Sher, Stepien, & Workman, 1995, p. 137) From the above statement a fourth key component of problem-based learning emerges. Problem-based learning

...is not just a problem-solving strategy, it is also good curricular material. Problem-based learning problems are constructed around
predetermined learning goals, conceptual focus, and disciplinary relevance. Content is far from being incidental to this form of problem solving, rather, PBL is considered to be a more effective way to teach the “core” curriculum. (Gallagher, 1997, p. 338)

Specific tasks in a problem-based unit include developing a problem, identifying stakeholders, identifying information needs to understand the problem, identifying resources to be used to gather information, generating possible solutions, presenting the solutions and debriefing the entire process. (Gallagher & Stepien, October 25, 1999).

Every day we face ill-structured problems that effect our personal and professional lives. In solving these problems we strive to “build understanding largely through what we experience. We create meaning as much from efforts to answer our own questions as from what we read or hear.” (Delisle, 1997, p. v) According to Delisle:

this is the principal behind problem-based learning; a teaching technique that educates by presenting students with a situation that leads to a problem for them to solve. It is not just a way to get students to find a correct answer. Frequently the problems have no single “right” answer. Instead students learn through the act of trying to solve the problem. They interpret the questions, gather additional information, create possible solutions, and evaluate options to find the best solutions and then present their conclusions. (Delisle, p.v)
Students who were taught through problem-based learning become “self-directed learners with the desire to know and learn, the ability to formulate their needs as learners, and the ability to select and use the best available resources to satisfy these needs.” (Delisle, p.3)

The teacher takes on a different role in problem-based learning. According to Gallagher:

the teacher becomes a “metacognitive coach” and focuses his/her skills on encouraging students to think like expert problem solvers. The PBL problem, (an ill-structured problem) sets up the classroom so that the teacher can focus on helping students become self-directed in their thinking and their actions. The teacher as metacognitive coach shows students (through modeling and coaching) different kinds of questions they should ask at different points in the problem. (Gallagher, p. 340)

Through modeling “coaches facilitate student understanding by articulating the kinds of thinking behavior they want their students to exhibit. (Sage & Torp, p. 71) Eventually through modeling and coaching the students are required to take on the responsibilities of using these skills on their own. (Blakey & Spence, 1990, p. 12) This supports Vygotsky’s theory that “if a student receives adult guidance or collaboration with a more advanced peer, that student can proceed to solve the problem and real learning is possible.” (Borich, 1996.) But as Gallagher points out “if students are going to internalize the habits of good question asking, information seeking, and
reasoning these skills will have to be practiced again and again." (Gallagher, p. 353)

**Problem-Based Learning's Relevance to K-12 Education**

Torp and Sage suggest that:

PBL is a form of experiential education in which learners, think, know and do in an authentic context. Widely used in medical and business education for several decades, PBL has been used in its present form in K-12 education for only a few years. But the core of PBL – students as active problem solvers, making their own meaning – is an educational tradition dating back to John Dewey. (Sage & Torp, p. 27)

Delisle indicates that:

students educated for the world of the 21st century must develop habits of thinking, researching, and problem solving to succeed in a rapidly changing world...studies show that while students are making progress in learning basic skills, only a small percentage perform at desired grade levels and master higher order thinking. (Delisle, p. 4)

Delisle goes on to state that:

Problem-based learning fits right into the movement for higher standards and greater achievement. PBL asks students to demonstrate an understanding of the material, not just to parrot back information with a few word changes. Research and teachers' experiences have demonstrated that active instructional techniques like PBL can motivate bored students and raise their understanding and
achievement. These student-centered strategies build critical thinking and reasoning skills, further students' creativity and independence, and help students earn a sense of ownership over their own work. (Delisle, p.5)

“According to Reigeluth (1994) emerging features for a new educational system...include cooperative learning, thinking skills, problem-solving skills and meaning making, communication skills, and the teacher as a coach or facilitator of learning.” (Sage & Torp, p. 30) These features look very similar to the features of problem-based learning. “VonGlaserfeld (1989) indicates that we can show students that there is profound satisfaction in thinking one's way to a solution and that this satisfaction can generate the motivation to learn more.” (Sage & Torp, p.32)

PBL classrooms are learner-centered communities where information is collectively gathered and shared. In these learner-centered communities students become excited about learning through problem solving. Hewitt and Scardamalia's (1996) work on the knowledge-building community model supports Sage's and Torp's work with problem-based learning communities.

Hewitt and Scardamalia have identified the following characteristics of such communities:

1. Inquiry is focused upon communal problems of understanding where meaning is negotiated through questioning, theory refinement, and dialogue.
2. Students' ideas about what they need to know become the focus of inquiry.

3. Knowledge is shared and held collectively. New information that is shared has the potential of shaping subsequent investigations by others.

4. The artifacts of student inquiry are made public and used in knowledge production....

5. Responsibility for planning, organizing, questioning and summarizing is shared among the students and facilitated by the teacher. (Sage & Torp, p. 81)

These types of skills are not learned through traditional instruction but are developed through the direct experience of doing. PBL provides that experience.

There is another body of research that K-12 educators should find relevant. Gallagher summarizes this research. (Gallagher, p. 344) She indicates that the following research shows support for many of the assumptions of PBL.

1. Facts and skills are learned more effectively when students can work with information rather than passively receive information. (Resnick & Klopfer, 1989, Voss, 1989)

2. Ill-structured problems share the same format as real-world problems and thus support the kind of thinking and skill
development students will need after schooling is completed.
(Carter, 1988; Chand & Runco, 1993)

3. Both learning and motivation increase when the curriculum is based on problems of significance and thoughtful questions.
(Brown, 1990; Wiggins, 1989)

4. The acquisition of good dispositions toward learning may be one of the most important attributes of critical thinking for students to acquire. (Ennis, 1962; Newmann, 1992; Wilkinson & Maxwell, 1991).

Interrelationship between PBL and Metacognition

An important feature of problem-based learning is the development, practice, and support of metacognition. Yussen (1985) identifies metacognition as “that mental activity for which other mental states or processes become the object of reflection” and therefore sees it as important in solving well and ill-structured problems. (Boyce, VonTassel-Baska, Sher, & Johnson, 1997, p. 363). Barrows suggests that “...new and perplexing problems or situations require deliberation, reflection, review – or metacognition. (Barrows, 1988, p. 2) Barrows defines metacognition as:

...the executive function in thinking: pondering, deliberating, or reflecting on a problem or situation; reviewing what is known and remembered about the kind of problem confronted; creating hypotheses; making decisions about what observations, questions, or probes need to be made; questioning the meaning of new information
obtained from inquiry, pondering about other sources of information; reflecting on and reviewing what has been learned; what it all may mean and what needs to be done next....students must acquire through practice these well developed metacognitive skills to monitor, critique, and direct the development of their reasoning skills as they work with life's ill-structured problems. (Barrows, p.3)

In its simplest form metacognition is thinking about thinking.

Caroline, a student at the Friendship Valley Elementary School, wrote metacognition means to understand what you're thinking about. The teacher might ask you to describe what is going on in your head while you are thinking. Metacognition is important to know because you need to understand what you're thinking about so you can explain how you got an answer. (http://www.carr.lib.md.us/ccps/fve/stuex7.html)

Caroline was describing the hallmark of metacognition – reflective thought.

Reflective thinking is often understood to be the foundation for self-directed learning and self-directed learning is the foundation of problem-based learning. Gallagher discusses the relationship between reflective thinkers and self-directed learners. She indicates:

Expert problem solvers tend to be “hyperconscious” of their own thinking, that is, they are aware of their thinking processes, review them regularly, can describe them and change them when they are not effective. (Paul, 1993) The skill generally considered central to being
self-directed is becoming hyperconscious of thought. Metacognition – thinking about thinking- is the foundation of this consciousness. (Carr & Borkowski, 1988; Sternberg & Davidson, 1985) By reflecting and evaluating their thinking process, people acquire better control over their thinking and feeling processes, ultimately resulting in better reasoning. (Gallagher, 1997, p. 339)

The literature also connects this ability to acquire better control over their thinking with student's beliefs and attitudes. The literature indicates: Beliefs about the usefulness or uselessness of what is being studied (Lampert, 1986; Schoenfield, 1983); beliefs about the causes of success on cognitively demanding tasks (Andrews & Debus, 1978; Deci & Ryan, 1985; Dweck, 1985; Reid, 1987) and beliefs about the effectiveness of thinking (J. Baron, 1991) have been seen as important determinants of the quality of thinking and the effort that people are willing to put into it. (Nickerson, 1994, p. 421)

The attitudes and actions of students engaged in problem-based learning support this concept.

Developing Metacognitive Strategies

Metacognitive questions help students monitor their own thinking processes and consider appropriate strategies for solving problems. John Tompion, biology teacher, IMSA, explains the importance of metacognition with this thought: “Pasteur is quoted as saying ‘chance favors the prepared mind.’ Then the questions become – how do you prepare the mind? Is it
simply by knowing more stuff? Or knowing how to approach the problem?"
(Sage & Torp, p. 23)

Metacognitive instruction frequently addresses such issues as learning to develop goals and the steps to reach these goals; questions efficacy of strategies while in use; monitor one's progress and improves study habits and evaluates decision making, problem solving or both. (Boyce, et.al, p. 363)

These forms of analysis, synthesis, and evaluation are not learned through direct instruction but from the experience of participating in a problem-based learning unit.

Often children do not have the skills or experiences required to ask the right questions and teachers may need to model them. Barrows (1988) suggests a metacognitive coach must help students understand the questions to ask during problem definition, information location, analysis and synthesis and to sort through potential interpretation and/or resolutions. (Gallegher, p. 416).

Coaches can help students ask the right questions through the modeling of several metacognitive strategies. Following are three of these strategies.

**The Need to Know Board**

The freedom created by problem-based learning makes it necessary for students to follow a carefully planned process if they are to experience success. This may sound contradictory but the problem-based learning process steers students through the complex task of brainstorming
ideas, identifying useful knowledge, asking appropriate research questions, and crafting a strategy for finding answers. (Delisle, p. 26)

Within problem-based learning the most recognizable metacognitive strategy is the need-to-know-board. “The need-to-know board introduces students to metacognitive thinking since the three questions “What do I Know?” “What do I need to know?” and “Where can I find this information?” are important reflection for a good thinker. (Gallagher, p. 350) “Students use the need-to-know board as a focus for negotiation of the problem and as a place to co-construct knowledge.” (Hmelo & Ferrari, 1997, p. 410). The three-metacognitive questions are often translated onto the need-to-know board into four columns – ideas or hunches, facts, learning issues, and action plan. The structure of the need-to-know board is key for students to master. It is designed to help students think through situations and reach appropriate solutions.

Following the process requires students to think through each step before moving on to the next, and it prevents them from jumping too far ahead of themselves and making decisions about which solution is best. It also helps teachers keep track of what students have already figured out and what they will need to learn. (Delisle, p. 36)

“This device is a powerful tool for supporting the learning process, one that the facilitator must initially model to help students understand how to best use it.” (Hmelo & Ferrari, p. 410)
Mind Mapping

The concept or mind map is often used as a metacognitive strategy to get students to think about how their current activities related to their goals.

"Mind mapping is an invaluable tool for multiple purposes in problem-based learning." (Sage & Torp, p.49) "Mind mapping is one way to record thinking visually so that the thinking can be reviewed, organized and refined." (Sage & Torp, p. 51)

Students often have difficulty locating any information or they find such an abundance, much of it irrelevant, that they may initially struggle ... helping students maintain a focus on the problem statement is helpful in determining which information is needed and most useful. (Sage & Torp, p.40)

"Mind maps developed by students help them make the links between pieces of information and find the conceptual whole among disparate perspectives." (Gallagher, Sher, Stepien, Workman, p. 144) This strategy helps students refocus on the problem and question the usefulness of specific strategies and information.

Problem Log

Another metacognitive strategy is the problem log or journal. Students use the problem log to track their development in solving the problem. Unlike the traditional notebook it includes not only focus questions, research notes, and laboratory reports but also personal reflections. "Costa (1991) has
recommended such journaling or reflections as a way to develop monitoring and assessment skills. (Boyce, et.al, p. 370) The problem logs encourage students to reflect on individual progress or effectiveness of the work group. “Specific assignments planned for the log help coaches keep track of students’ thinking. Notes kept by students outside of formal assignments help them take advantage of sudden insights which might be helpful to the group.” (Gallagher, et. al. p.144)

Content

Students’ abilities to learn relevant content is directly affected by their awareness of metacognitive skills and development of positive attitudes toward learning. Mastery of the metacognitive strategies of the need-to-know board, mind mapping and problem log indicate an understanding of relevant content. These strategies allow for “plenty of opportunities to assess content acquisition through open-ended questions...and prompts to describe their understanding about the details of different elements of the problem.” (Gallagher, et.al., p. 144)

Research supports the concept that problem-based learning is a “vehicle for examining issues in the content domain. It is designed to help students develop the ability to critically thing and problem solve in the content domain.” (Duffy, April 26, 1999) With teacher direction through modeling and embedded instruction students are able to “synthesize and construct knowledge to bring resolution to the problem in a way that meets the conditions they themselves set forth.” (Sage & Torp, p. 26)
Part Three: Methodology

Introduction

A qualitative approach was used in this study to determine if teacher modeling of metacognitive strategies, within a problem-based learning unit, would help students become independent, reflective thinkers. This section will describe the methodology used. Besides specifying the demographics and study population, this section will show how the unit of study was carried out and how the data was collected and analyzed. Specific attention will be paid to the instruments used to gather data.

Study Background

After immersing myself in the study of problem-based learning I came to see it as a method for helping students develop into reflective thinkers by learning to use information in a logical, useful way. To test this belief I developed a unit of study based on the problem-based learning process. With this process students work through a problem by asking:

- What are my ideas or hunches for a solution?
- What do I know?
• What do I need to know?
• What should I do?
• What did we do that was effective in solving the problem?

I hypothesized that by modeling this process I would be able to encourage students to adopt the process as a way to solve a problem. Throughout the unit of study my intent was to provide opportunity for support and reflection on both the content learned and the learning process.

Study Sample

Demographics

I teach at the James Madison School of Excellence, one of seven middle schools in the Rochester City School District, Rochester, New York. This urban school district has an enrollment of approximately 33,000 students. James Madison has about 1250 students enrolled in grades six through eight. It is considered a community school with 90 percent of the students drawn from the immediate neighborhood. The overall enrollment of the school is 98 percent African-American. The remaining two percent is mainly Hispanic. The majority of families are classified within a low-income bracket, with 89 percent eligible for the free lunch program.

James Madison School of Excellence opened its doors in September 1998. It provides up-to-date science and technology facilities. A neighborhood
community center is attached to the school and provides after school programs to many of the students.

**Study Population**

I completed this teacher research in my seventh grade Major Achievement Program (MAP) science class of 24 students. The class consisted of fifteen females and nine males.

The MAP program was founded in 1964 to meet the needs of intellectually talented children early in their educational experience. Selection criteria, as established by the district, includes:

- High achievement in reading and math standardized tests.
- Cumulative school record of outstanding performance.
- Principal and teacher recommendations.
- Portfolio submissions that show evidence of creative and productive thinking.
- General intellectual ability shown in classroom performance.

The last standardized tests taken by this class were the 1998 California Achievement Test in Mathematics (CAT) and the 1998 Degrees of Reading Power (DRP). Forty-one percent of the students placed in the 90th percentile or above for the CAT. There was a significant gap between the math computation portion of the test and the math application portion. Computation scores were much higher in almost all instances. Only 21
percent of the class placed in the 90th percentile or above for reading. (See Appendix A)

There was a wide spread in end of year averages in English, Social Studies, Mathematics, and Science among all students. The highest grades were in English and the lowest in Math. MAP students are enrolled in Math 8 during the seventh grade year. (See Appendix A)

PBL Unit of Study

Unit Development Background

I created this unit of study (see Appendix B) based on my desire to research student adoption of metacognitive strategies through problem-based learning. The content — force, motion, and simple machines— was dictated by the curriculum. The unit was taught over fifteen days during May and June 2000. There were several breaks in instruction for standardized testing, parent-teacher conference days, and field trips. Students were on a field trip the entire week of May 22 and again on June 9. There were also a gap between the last day of formal classes on June 6 and June 12 when students gave their final presentations. This definitely affected the continuity of the study. Classes were scheduled to meet every other day for seventy minutes. This schedule was often modified with some classes being shortened to between 30 and 50 minutes due to testing. For this unit of study students were assigned to one of six mixed-ability teams. There were four students to a team.
Students were first introduced to the general idea of problem solving by listening to my personal story of how I lost my house keys, how I reacted and how I eventually solved my problem. As I told my story, a peer teacher, Joanne Bell, held up word strips at appropriate times. The word strips indicated general problem solving strategies such as reflecting, monitoring behavior, planning, communicating, identifying alternatives and evaluating.

Students then reflected in their problem logs on a personal problem that they solved and shared with their team. After sharing they returned to their problem logs and wrote ideas for better ways to solve their problem and/or identified the problem solving strategies they used. This opening activity was meant to help students think of problem solving as a process.

The Hook

Students were introduced to the problem through a memorandum I wrote and delivered to them in a professional looking presentation folder. (See Appendix C) The subject of the memorandum was: Request for Proposal: Fun House Challenge. Through this memorandum students were advised that their challenge was to design activities for a fun house that could be run by one or more simple machines. The memorandum indicated they would have to present their solution to a panel of school personnel. Time constraints and presentation criteria were included.
The Process

Early on in problem-based learning units students need to make conscious decisions about their knowledge. A common metacognitive strategy used in problem-based learning units to help students make these decisions is the need-to-know board. Therefore, the need-to-know-board was the metacognitive strategy that I introduced at this point in the unit. (See Table 1) Steps were introduced one at a time. Students experienced one step before moving on to the next. The need-to-know board was displayed for the duration of the unit. Students were encouraged to revisit it as needed. Students were also given a typed copy of the results of each step. A student volunteer typed the results of each step.

<table>
<thead>
<tr>
<th>NEED TO KNOW BOARD</th>
<th>A Problem-Based Learning Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDEAS</td>
<td>FACTS</td>
</tr>
<tr>
<td>Possible solutions to the problem.</td>
<td>What we know</td>
</tr>
</tbody>
</table>

Table 1: Metacognitive strategy used to help students make conscious decisions. Adapted from work by Gallegher and Stepie, Barrows, and Delisle.
When the students reached the point of beginning their research, work came to a stand still. Frustration and off task behaviors were apparent. I sensed they did not know where to begin. They did not have an explicit model to follow. It was at this point I introduced the strategy of mind mapping. In their teams students grouped the learning issues into common clusters and created mind maps. In small groups and then as a large group they discussed how each team grouped the learning issues; why they placed specific learning issues in specific clusters; and which group would be best to research first and why. This mind mapping strategy helped students prioritize their needs. It helped the students refocus on the problem and question the usefulness of specific strategies and resources. This strategy allowed students to move forward again. The value of the mind map as a metacognitive tool proved valuable.

Once students had a need for knowing specific information I introduced an embedded instruction. I provided students with focus questions on force, motion and simple machines. (See Appendix D) I showed a video on simple machines. I explained that from listening to group discussions I thought the video might help answer some of their questions. I suggested the focus questions might help them organize their thoughts as they watched the video. I did not require them to answer the questions but only suggested they might be helpful while researching their learning issues. Many used the questions not only as they watched the video but also as they continued to read pertinent articles on simple machines. Almost all students included
notes on some or all of the focus questions in their problem logs. Many included drawings stemming from their perceived answers to the focus questions. Their answers to the focus questions, research notes and drawings were placed in their problem logs.

Classroom resources, including books, magazines, videos, CD programs, Internet access, Lego and K'nex kits supported student research. The school library was being used for testing during this time and I was unable to reserve it. Individual students took the initiative to use their own sources, including visiting their community library, visiting stores, and interviewing experts.

At the end of each day students were given reflective journal questions to answer in their problem logs. Journal questions were drawn from a bank of questions that I created. (See Appendix E) The questions used depended on what had happened that day. Students were also encouraged to keep general notes, diagrams, research findings, and presentation outlines in their problem logs. Problem logs were kept in the classroom but students often requested copies of specific pages. At the end of each class I would read student reflections and respond in each problem log with comments and questions to them. Problem logs were evaluated through the use of a Learning Log Rubric. (See Appendix F)
**The Resolution**

Toward the end of the research period I gave the students a set of presentation guidelines. (See Appendix G) These reinforced the original RFP presentation criteria. On the last day of the unit student teams presented their problem resolutions to the Vice Principal of Curriculum, McNair House Administrator and the International Middle Years Coordinator. These people acted as evaluators. They were given a rubric to complete for each presentation. (See Appendix II) At the end of the presentations student teams received and debriefed their presentation evaluations.

**Summative Reflection**

Students completed a summative reflective piece that I created. They completed this summative reflection during their final examination. This reflective piece was titled Think Back. (See Appendix I) This was a summative reflective piece which asked students to comment on the processes they used to solve the problem; how they finally were able to begin their research; what they learned from the project; what part the journal played in completing the project and how their participation in this project was different from participation in other projects.

**Data Collection Methods**

Data collection included responses from student problem logs and responses from the summative Think Back reflective piece. Additional data was gathered from my field notes, comments from Joanne Bell, a peer observer, and a videotaped focus group of nine students. At least one student
from each team participated. The focus group interview was designed to collect descriptive data in the students' own words and to develop insights about the students' perceptions, experiences, opinions and feelings. The focus group interview lasted for approximately 90 minutes. As part of the focus group protocol I asked students to look at another problem and the need-to-know board of another group of students. (See Appendix J) I told them that since they had just gone through a similar experience I thought they might be able to make recommendations to these students on how to solve their problem. I asked them to analyze the problem and need-to-know board and give advice on solving this problem.

I had originally intended to audiotape and videotape students working in small groups but found this did not work. The noise level (even though students were on task) was too high and created garbled tapes. Also, because I was sharing a room it was impossible to set up the tape recorders ahead of time. It took several minutes at the beginning of each class just to rearrange the seats and put up the need-to-know boards and mind maps.

My plan to use think-alouds at the end of each class also did not work. Students were unable to listen to each other in a large group. Shortened class periods due to testing also made think-alouds an inefficient use of class time. Written problem log responses seemed to be a much better use of time plus students were much more open to journal writing.
Part Four: Study Findings

Introduction

In this section I will report my findings. I will analyze results for each research question. First, I will discuss the findings for research question one—the adopting of metacognitive strategies modeled by the teacher. Aspects of metacognition that will be addressed are behavior, attitudes, and beliefs and metacognitive strategies. Next I will discuss indications of growth in the way students talk about their perceived ability to solve problems. Lastly I will analyze whether or not these metacognitive strategies helped students acquire content knowledge. Writings from student problem logs and summative reflections support findings. Findings are also supported by quotes from the focus group interview. Additional support comes from my field notes and peer comments.

Research Question One

Behavior, Attitudes, and Beliefs

As my peer observer, Joanne Bell noted “the students very quickly seemed to have moved from feeling that this is just another assignment to seeing it as a project they owned and valued.” I too saw swift positive changes in behavior, engagement and quality of work. As indicated earlier, acquisition of good dispositions toward learning may be one of the most
important attributes of critical thinking for students to acquire. (Ennis, 1962; Newmann, 1992; Wilkinson & Maxwell, 1991).

There was a dramatic change in student behavior, attitudes, and beliefs. Students showed increased motivation to learn. From the beginning students were engaged in the learning process. There were fewer behavior problems, greater communication between the students and myself and an increase in the quality and creativity of student work. As one student (Laverne) said “this project seemed made for us, it was real, we did the whole process ourselves. We chose to do it.”

One of the students in whom I noticed a marked change in attitude was Chuck. On day 3 of my field notes I observed:

The change in Chuck’s attitude is amazing. Ever since September we have had our daily confrontation about rules. The conversation would go something like this... “Please take your bookbag back to your locker. You know you can’t bring it into the room.” He takes it back. Later on I say “Chuck, where is your pencil?...in your bookbag?...ok use one of mine...Chuck, please follow directions...Yes I know but sometimes thing aren’t fair”...This dance has completely stopped. He is on time, with no bookbag and with all his required tools, including pencils.

On day five of my field notes I wrote:

The change in Chuck is amazing. He’s actually volunteered (for the first time) to come in on his own time and word-process the need-to-
know board lists...and while doing this on every page he wrote (in bold and italics): Typed by Chuck.

His problem log also sheds light on this change in attitude when he wrote:

I now know that I am not supposed to get worried right away. Solving problems are not as hard as I thought.

And his summative reflection indicated a connection to his real world and a feeling of pride when he wrote:

One thing I found out is I use simple machines all of the time. When I build a ramp out of bricks or cardboard and ride my bike up to the ramp to see how far I can jump I found I am really riding my bike up an inclined plane. I learned that when I am driving my cousin's go-cart I am using a wheel and axle to move the go-cart. Wait until I show them how much I know!

Then there was Sack, who seldom said anything. His only offering this year has been laughing at the antics of others. He seemed to blossom in this project. I often noticed him actively interacting with his team. He began to volunteer his thoughts during whole group discussions. Comments in his problem log and summative reflection indicate a feeling of empowerment. On his Think Back he wrote:

In this project I felt I could express my feelings more than any other project. This project made learning and communicating easier for me. Every since I did this project I became more open with my ideas. I also participate more since this project. Before this project I used to just sit
in class and listen. I honestly think this project was interesting. I know for a fact that I learned a lot. I had a lot of fun doing this project. I was successful too with the help of my group.

And at another point he wrote:

I think my group and I got along well. We had a couple of arguments but we managed to work things out... Our project made sense. I'm glad we talked ours out. We planned what we were going to make and we finished our project. We were very successful and we did a well job.

During the focus group, student comments clearly showed strong positive believes and attitudes. As I report this dialogue I only wish the energy and enthusiasm in their voices could be reproduced.

Teacher: I noticed the way your groups approached this project was very different from other projects – the quality and creativity of your work was different. Why do you think there was such a difference?

Laverne: This project seemed made for us, it was real, we got to do whatever we wanted to do, got to think about it and we did the whole process ourselves.

Tiffany: We were interacting with it, you just didn't tell us what to do and I liked that. I also like the way you started – with the funny story about solving an impossible problem. It made me feel good.

Jane: You were on your own; you got to think about what you wanted to do and didn’t want to do.

Kelly: You had more choices.
Leslie: It was challenging.

Sack: Everyone participated, the journal really helped me express my thoughts and feelings.

Holly: Like the others said, it was hands on, you actually know you can be involved with it, makes you more eager, more interested.

And lastly my field notes for June 9 indicated a change in behavior when I recorded this observation:

Boy was I surprised! It is 2:30 p.m. Our house has just gotten back from Seabreeze and students from four of the six groups have shown up to work on their project...on a Friday and after Seabreeze! Several did not leave until 4:30 p.m. When they did leave they took Legos, markers and poster board with them. This has to be commitment!

The above snapshots illustrate the behavior and attitude changes of most of the students. They show a belief in themselves. They convey a feeling of ownership, engagement, and empowerment.

Metacognitive Strategies

The findings suggest that the students were able to think through a problem using teacher modeled metacognitive strategies. Using these strategies students accepted the responsibility to learn on their own. Through their actions and comments they showed that they were aware of the process that included planning, monitoring, and evaluating. Though they still needed a great deal of direction they understood that there is a way of thinking to solve real life problems. They were able to use what I modeled to solve this
particular ill-structured problem, though this does not mean they internalized this way of thinking. Reading through their problem logs and summative reflections I could see growth in their thinking and ability to use modeled strategies to learn content and to solve problems.

With some direction, through teacher posed questions, students gave meaningful, reflective responses. Sack said it eloquently when he wrote:

I felt like I could express my feelings more...this project made learning and communicating easier for me. I was successful.

Holly added her words of wisdom when she wrote:

To do one thing you have to know another – this process is more about whether or not you understand it than did you get the work done.

**Strategy One: Need-To-Know Board**

At the most basic level most students could describe the process they used to solve the problem. (See Table 2) Most included entries such as:

The process was to come up with ideas. Then we used the need-to-know sheets. We asked questions. Then we asked questions about materials, costs, etc. Then we made an action plan to see what we needed to do to solve our problem. (Tina)

Today we have listed all the facts we already know about what we need for this simple machine problem. Then we got to share our questions with each other. After that we thought of where we could get information. We came up with a lot. (Leslie)
We started our process sheets. They were about how we are going to make the fun or haunted house. We wrote on the process sheets more facts, learning issues and action plans. We talked about ideas that we made up. (Katie)

Many students showed a more in-depth understanding of this strategy when they wrote:

My group was sort of stuck on some questions we did not have the answers to. So we wrote down what we knew already and then we took some books and then we learned from the books. We also used kits to help. (Kari)

We did many things to solve our problem. We brainstormed all of our ideas to create a fun house run by simple machines. We watched a movie on simple machines to help us build our ideas. We did a mind map to organize our research. We did research at the library on simple machines. When we were stuck we thought out our problems and went back to the problem. (Ben)

What I did for research was go back and remember what I saw on the movie and what they said. Also I decided what I knew for a fact and what I needed to know before I did the research. 2/3’s of our questions were based on other questions. (Holly)

The procedures that we used were we analyzed the problem, we looked at our choices, formed a hypothesis, made some observations and came up with a conclusion. When many of the groups were stuck we watched
two movies involving simple machines. We also made a mind map and made charts of ideas that could be run by simple machines. Another thing we did was form a research chart that showed how we could answer our questions. (Jay)

A few students seemed to be able to transfer this strategy away from the immediate problem and to the general idea of problem solving. Comments supporting this observation included:

One thing I learned about solving a problem was you must plan, communicate, and evaluate the problem. The thing that really surprised me was all of the planning in solving one problem. (Tina)

One thing that I learned about solving a problem is that you have to go through all of the steps, plan what you will do and how you are going to solve your problem. The thing that really surprised me was when I lost something over the weekend I used the steps and quickly found it. (Kari)

One thing I learned about solving a problem is that you really need to think it out. You need to think step by step. The thing is I was already doing some of this in my mind without knowing it. (Ned)

As part of the focus group I asked the students to look at another problem and the need-to-know board another group of students had developed. (See Appendix J) I then asked them what would they do next? Their initial responses to this problem were very different from their original Fun House problem. Instead of waiting for my directions they plunged right
in and began talking to each other. It was interesting that when focus group participants were presented with the playground scenario they focused on need-to-know and identified research questions and action plans rather than jumping right to a solution. They were beginning to identify what is relevant and useful as well as searching for new content. In answer to the question what would you do next the dialogue was as follows:

**Laverne:** We need to start by focusing on what we need to know.

**Tiffany:** Yeah, using the what we need-to-know questions you need to connect research to the question.

**Jane:** Need to assign the different questions to different group members, then come back and share results.

**Kelly:** You need lots of research before making decisions, after research go back and look and look at the facts and the starting problem.

**Jane:** You need a step in between learning issues and research, you need to do a mind map.

**Kari:** Or a chart that relates common questions.

**Holly:** You need smaller questions under each learning issues topic. It will make research easier. You’ll know where to go. You might need to go back and brainstorm again.

At this point in the discussion the students turned their talk to the action plan and came up with many unique ideas. This was a very different approach than when they worked on their own problem. When they first
discussed their first problem they waited for directions and offered common research sources.

Also the way they discussed how to approach this group's need to present was different from their original approaches on their Fun House Challenge. In the Fun House Challenge they started out discussing how would they present their solution (i.e. poster, model, game) but during this discussion they focused more on what did they need or how would they get the information to present. They seemed more in tune to what needed to go on before they organized the presentation. Part of the dialogue included these thoughts:

**Tiffany:** Before presenting they must take a look at all the research.

**Holly:** You have to research, compare, research, put together and then present.

**Jay:** You need a chart to show how you will put it all together.

**Jane:** You need a chart with topics, like regulations, safety, fun, cost. Then you have pros and cons for each. Check them off. Does the idea have all the qualities? Take what passed the test and put together new ideas.

**Kelly:** Most important you have to explain in the presentation how did the ideas pass.

**Laverne:** If I had questions I would go back and think about it after getting information from the problem log. I remembered questions I need to answer.


### Need to Know Board for Fun House Challenge

<table>
<thead>
<tr>
<th>Ideas</th>
<th>Facts</th>
<th>Learning Issues</th>
<th>Action Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Funny Mirror</td>
<td>Must give specific explanation of how device will work.</td>
<td>What is a simple machine?</td>
<td>Get information form TV</td>
</tr>
<tr>
<td>Maze with trap door</td>
<td>The device must run by a simple machine.</td>
<td>How do you build a simple machine?</td>
<td>Kits</td>
</tr>
<tr>
<td>Trick mirror</td>
<td>It will cost money.</td>
<td>How does a simple machine work?</td>
<td>Books from library</td>
</tr>
<tr>
<td>Trick slide</td>
<td>It has to be fun.</td>
<td>How can we make a ride out of a simple machine?</td>
<td>Interviews: technology teacher, engineer, architect, community groups, parents, store clerks</td>
</tr>
<tr>
<td>Power Ranger watch</td>
<td>It can’t be a lot of money.</td>
<td>What materials do you need?</td>
<td>Internet</td>
</tr>
<tr>
<td>Invisible spider web</td>
<td></td>
<td>How many different types are there?</td>
<td>Observe amusement park activities.</td>
</tr>
<tr>
<td>Illusion Floors</td>
<td></td>
<td>What simple machine would be the best to use?</td>
<td>Books in science room</td>
</tr>
<tr>
<td>Haunted pyramid</td>
<td></td>
<td>Where are we going to put the Fun House?</td>
<td>Go to a store involved with building/ask questions.</td>
</tr>
<tr>
<td>Scary tunnel</td>
<td></td>
<td>How much will it cost to build?</td>
<td>Models</td>
</tr>
<tr>
<td>3D roller coaster</td>
<td></td>
<td>What simple machine would be the best to use?</td>
<td>Other students</td>
</tr>
<tr>
<td>Travel machine</td>
<td></td>
<td>Where are we going to put the Fun House?</td>
<td>Look at nature</td>
</tr>
<tr>
<td>Shoe tying machine</td>
<td></td>
<td>How much will it cost to build?</td>
<td>Videotapes</td>
</tr>
<tr>
<td>Flying bats</td>
<td></td>
<td>What simple machine would be the best to use?</td>
<td>Experiments</td>
</tr>
<tr>
<td>Pop-out skeleton</td>
<td></td>
<td>Where are we going to put the Fun House?</td>
<td>Magazines</td>
</tr>
<tr>
<td>Blair-witch signs</td>
<td></td>
<td>How much will it cost to build?</td>
<td></td>
</tr>
<tr>
<td>Invisible scarecrows</td>
<td></td>
<td>What simple machine would be the best to use?</td>
<td></td>
</tr>
<tr>
<td>Chucky doll</td>
<td></td>
<td>Where are we going to put the Fun House?</td>
<td></td>
</tr>
<tr>
<td>Bleeding scream</td>
<td></td>
<td>How much will it cost to build?</td>
<td></td>
</tr>
<tr>
<td>Scary breathing</td>
<td></td>
<td>What simple machine would be the best to use?</td>
<td></td>
</tr>
<tr>
<td>Dripping blood</td>
<td></td>
<td>Where are we going to put the Fun House?</td>
<td></td>
</tr>
<tr>
<td>Grey fog nasty smell</td>
<td></td>
<td>How much will it cost to build?</td>
<td></td>
</tr>
<tr>
<td>Go cart roller coaster</td>
<td></td>
<td>What simple machine would be the best to use?</td>
<td></td>
</tr>
<tr>
<td>Bumper cart paint gun splash</td>
<td></td>
<td>Where are we going to put the Fun House?</td>
<td></td>
</tr>
<tr>
<td>Feather tag</td>
<td></td>
<td>How much will it cost to build?</td>
<td></td>
</tr>
<tr>
<td>Scream</td>
<td></td>
<td>What simple machine would be the best to use?</td>
<td></td>
</tr>
<tr>
<td>Thieving game</td>
<td></td>
<td>Where are we going to put the Fun House?</td>
<td></td>
</tr>
<tr>
<td>Chucky jumps out with knife</td>
<td></td>
<td>How much will it cost to build?</td>
<td></td>
</tr>
<tr>
<td>Swing axe</td>
<td></td>
<td>What simple machine would be the best to use?</td>
<td></td>
</tr>
<tr>
<td>Moving walls</td>
<td></td>
<td>Where are we going to put the Fun House?</td>
<td></td>
</tr>
<tr>
<td>Floors open/car goes down hills</td>
<td></td>
<td>How much will it cost to build?</td>
<td></td>
</tr>
<tr>
<td>Car through wall of water</td>
<td></td>
<td>What simple machine would be the best to use?</td>
<td></td>
</tr>
<tr>
<td>Skeleton drops from ceiling</td>
<td></td>
<td>Where are we going to put the Fun House?</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Student results of working through the need-to-know board process.
Strategy Two: Mind Maps

The value of the mind map (See Figure 1 and Table 3) as a metacognitive tool was supported through student reflections. Student written comments included:

We developed a learning issues mind map so we would know what questions we needed to research before we could even work on the true problem. We prioritized the simple machines learning issues because you need to understand one thing before you can understand another. (Holly)

My group developed a learning issues mind map because we needed more information about simple machines. We prioritized the simple machines learning issues because we needed to know what to do. We also needed to know when and why we needed to do these things and what order they must be done in. (Sack)

The reason why we did a map was to organize our questions and see how the questions relate to the challenge. Also to spread out our questions to really understand what we have to do. I think making a map really helped me spread out the questions, organize, and understand because before this all the questions were jumbled up in my head. (Tiffany)
How do we make this ride safe?

Safety

What materials do we need?

Materials

Where will we buy them?

How much will they cost?

How will we attract people?

Marketing

Where will we advertise?

How to Build a Fun House Using a Simple Machine

Simple Machines

What is a simple machine?

How do you build a simple machine?

How does a simple machine work?

How many simple machines are there?

How can we make a ride out of a simple machine?

Which simple machine is the most realistic for our idea?

Can we hire someone to help build it?

Cost

How much will it cost to build?

Where will we get the money to build our idea?

Time

How long will this take to build?

When and where will we build it?

Figure 1: Student example of Mind Map.
I think researching simple machine learning issues first is good because first if we are supposed to make a simple machine we need to understand what a simple machine is and know examples of simple machines so we can at least know what to do. If we started for example with materials our project would be unorganized and make no sense. We would not know what a simple machine is and what to do. We prioritized because it was more than five questions so we had to organize and spread out our ideas. Simple machines were the most important category. (Kari)

My group developed a mind map because that way we could see our obstacles flat out. Like all the questions we have will be on one paper. We need to research simple machine issues first because that is what our ideas will work from. We got unstuck by making a mind map and breaking down the project to see what we had to figure out to keep going. (Ned)

We made a mind map to organize all of the questions that we needed for our activity. The mind map also helped us organize, see data, plan – see clearly what we had to do. I think that really helped because all those questions were mixed up in my head and when I saw the map it was clear what I had to do. (Katie)

At the point when I was starting my research I got stuck because I really was at a point where I didn’t understand how to begin my
research. So the whole class had to think of this, to put on a mind map. The mind map really helped me out a lot. After it I started thinking on what I had to do next. (Anna)

Due to the fact that many of us were "stuck" on ideas to start our research we put together a mind map. This was a large paper that helped us think out our problems and ideas and come up with some solutions as to how to build or make what we planned. This mind map really helped many of us out. It got a lot of ideas out in the open. Then we knew what we could do and what we couldn't do to succeed in doing this challenge. (Jackie)

**Strategy Three: Problem Log**

The students summative reflection indicated their problem logs played an important role in helping them plan, monitor, and evaluate their progress. It also acted as a two-way communication between individual students and myself. Student reflections about their problem logs included:

The part journal questions played in completing this project are that they helped me understand the project more. The journal questions helped me because I had somewhere I could ask questions and get them answered. (Anna)

The journal questions did help because if I was stuck I could read my journal and it would really help me on what I was stuck on. (Chuck)

The journal questions that we did helped us a lot during this project. It gave us something to look back on for reference and some place to
write our thoughts and progressions during the project. Also what we learned. (Kelly)

The journal questions did help me out a little bit. They helped me think more about exactly what my task was and what the best way was to complete it. It was okay to write in the journal just to see if you and the teacher were on the same page. So that journal was a good idea. (Jackie)

Then in our journal we had to write down all the things we did every day and answer questions about the project. I had thought it was a waste of time until the end when I got good information from my journal and it really helped me with the presentation. (Laverne)

During this project I had a journal or log. Each day I was assigned a different entry about this project. My journal helped me express my feelings, opinions, and ideas. I think I can express my feelings more when I write. I had many good suggestions and I also received many suggestions. The journal played an important role in this project. (Sack)

During the focus group the students were very emphatic about the importance of the problem log (or journal as they chose to refer to it). Our conversation was:

**Teacher:** How important, if at all, was your journal?
Holly: It showed what we knew and now know. That changes a lot. Your point of view changes a lot. When you realize what you now know it helps you decide what to do.

Kelly: When you were stuck you could go back and see what we did. It was a place to put down thoughts.

Kari: I went back and looked at my notes.

Jane: My journal started with questions and ended with a solution. You could see it.

Tiffany: It was like a notebook. It kept me organized. Comments you wrote made me look further into it and come up with more ideas than I had. I made changes in my mind.

Laverne: It didn’t help in the beginning but at the end I looked back at it and it helped make my presentation better.

Strategy Four: Focus Questions

Support for students ability to adopt the modeled metacognitive strategies was illustrated through part of the focus group dialogue. The students indicated the focus questions helped them. From their conversation the context in which these questions were offered by the coach seemed very important. They accepted them as more than just questions to answer in order to receive a grade or questions to answer because the teacher assigned them. The conversation on focus questions included:

Teacher: Was there anything else you can think of that helped you solve your problem?
Tiffany: Those questions. You know the list of questions you gave us to answer.

Teacher: You mean the focus questions?

Tiffany: Yes. They were helpful in getting started. They helped me realize what we had to do. They were a point to start from.

Jane: They acted like guidelines.

Holly: I looked at the focus questions then back at the requirements and based my research on them.

Jane: I looked at each question and asked how much would we get out of it. Some were more important questions than others. It came down to four questions and we built on them.

Kari: We also built on each other's questions and tried different models.

Tiffany: One question would lead to other questions. Like a web and then those questions would lead to an answer and then to another question.

Teacher: Well what if I just gave you the questions but no problem. What if I said we have to learn about simple machines and you can learn about them if you answer these questions?

There was a resounding no from all students.

Kelly: The focus questions helped because we had ideas first. We had goals to reach. The problem helps us visualize the questions.

Holly: The problems helped us understand the questions, understand what was going on. We had a reason for doing them.
Laverne: We used them and learned at our own pace.

Leslie: The problem made it more creative.

Kelly: I used my imagination and was eager to know the answers.

Sack: The problem made the questions fun.

Research Questions Two

This unit spanned far too short a period of time to show major growth in students' internalization of problem solving strategies. Results did indicate that students' comments showed an awareness of not only metacognitive strategies but also a beginning synthesis of the importance of thinking about planning, monitoring, and evaluating their own thoughts. Growth in the way students talked about their ability to problem solve was seen in their writings and final presentations. In the beginning problem log reflections were short and concrete, revolving around the Fun House Challenge details. But by the time they completed their summative reflection, comments were more general and tended to discuss the importance of understanding, communications, teamwork and planning. Supporting comments that showed increased reflecting on metacognitive ideas included:

This process it was more about whether or not you understand it than just did you get the work done. (Holly)

As a group we asked each other questions. We took the time out to look back through papers. We would know where we went wrong and how to fix the problem. (Katie)
My participation in this project was different to any other project because I worked in a group and listened to everyone's ideas, improved on them and/or told them why it wouldn't work. We had to use procedures we never knew existed and then we had to pitch in. (Kelly)

I learned a better way to figure out problems on my own from the mind map. I learned that when I brainstorm I get a better conclusion. I liked this project because it was a great challenge. (Ben)

With this project you really had to think, everything wasn't just handed to you. You had to do your research and then share it. (Marcy)

I learned from this project that even though people don't get along they must put aside their differences and work as a team because four heads are better than one. (Max)

This project has taught me about teamwork. With us taking and sharing notes in our journals I thought it helped us better understand what we were doing. (Kathy)

Positive student talk was seen as student teams presented their final presentations. They were able to articulate how and why they solved their problems. They were able to think on their feet to answer judges questions on their final products. They were also able to discuss why they were able to produce quality work.

Student products and presentations were not perfect but were significantly better than any other assignment they had completed this year. On the day of the presentation all 24 students were present and 20 of the 24
were well prepared. Normally on the day of project presentations several students are absent. Though there is a need to work on presentation skills the majority of the students presented well thought out solutions accompanied by various visuals. Four of the six groups received 4's and 5's from the judges and the recommendation to "go forward with the idea."

Judges comments included:

Good introduction. You clearly explained what and how your device worked. (Judge 1)

Excellent response to our questions. You convinced me your idea will work. Presentation shows a great deal of preparation. (Judge 2)

Your posters and model coupled with your explanations really helped me understand how your device works. (Judge 3)

Only one group received ones and twos with the observation "does not demonstrate adequate preparation.

Research Question 3

Qualitative results established a positive relationship to content. Student's ability to learn relevant content was directly effected by their awareness of metacognitive skills and positive attitudes toward learning. Content to the students was important when they had a goal, a reason for knowing and understanding.

Student reflections indicated an understanding of relevant content. Students were able to "synthesize and construct knowledge to bring resolution to the problem in a way that met the conditions that they
themselves set forth.” (Sage & Torp, p. 26) Or as one student wrote “learning the facts is important because we have goal.” (Jay)

In the beginning students looked to me to answer their questions. Almost every problem log asked the question what is a simple machine? For the first two or three problem log entries students kept asking a variation on this question. Frustration showed in one student’s problem log entry when she wrote: “please tell me what is a simple machine, please, please, please!” But once students identified the learning issues they began to write a variation on the comment I need to find out what is a simple machine. Once the learning issues were identified students needed guidance in establishing content focus. But by introducing them to mind mapping they were able to prioritize (See Table 3) and focus their content needs.

<table>
<thead>
<tr>
<th>Prioritized Learning Issues List</th>
</tr>
</thead>
<tbody>
<tr>
<td>What We Need To Find Out About Simple Machines</td>
</tr>
<tr>
<td>1. What is a simple machine?</td>
</tr>
<tr>
<td>2. How many different types of simple machines are there?</td>
</tr>
<tr>
<td>3. How does each simple machine work?</td>
</tr>
<tr>
<td>4. How do you build a simple machine?</td>
</tr>
<tr>
<td>5. What simple machines would be the best to use for our ideas?</td>
</tr>
<tr>
<td>6. How realistic does (do) the simple machine(s) need to be for our solution?</td>
</tr>
<tr>
<td>7. How can we make a ride or activity out of these simple machines?</td>
</tr>
</tbody>
</table>

Table 3: After mind mapping the learning issues, students identified the simple machines cluster as the concepts that needed to be researched first. They then prioritized the concepts.

Student journal reflections indicated they used the focus questions as a guide in deciding how to prioritize the questions. I also observed they did not copy answers from a book for each question. They connected the questions
to their need to know. Of the focus questions Jane said her group “looked at each question and asked how much would we get out of it? Some were more important than others. It came down to four questions and we built on them. Isn’t that like prioritizing?”

One problem log question asked students to discuss “what do you know now that you didn’t know when you started?” Many students discussed process, how to solve a problem, rather than content. When students did discuss content it often appeared superficial. A common response was ‘I know what a simple machine is, how many there are and how they work.’ Students usually listed the six types of simple machines.

But deeper explanations came out in their presentations as they explained how their models worked. When they fielded questions from the judges most students were able to explain how the models worked using appropriate vocabulary. Summative reflections also showed a greater depth of understanding. Several summative comments indicated a general understanding that machines make work seem easier and can change direction or amount of a force or the distance or speed of a force. When asked to summarize their research (what do you know now) students’ responses about content included:

I needed to get books from the library. I needed to talk to someone like a carpenter. I think interviewing a carpenter, architect or technology teacher will be a great idea and they are experienced and can give me answers. (Sack)
So far I answered my question on what is a simple machine and my other question on how many simple machines are there. I have worked on a sketch of the carts and track we are going to use for our rollercoaster. We have also put down all the simple machines that we could use to make a rollercoaster. Later she wrote...we changed our idea because we found out for a rollercoaster you need an engine but simple machines don't use engines. So we changed our idea to a water slide. (Laverne)

The first thing we did was figure out what a simple machine was. When we found out a simple machine is something that makes work easier we started to learn about all of them. The simple machines are wheel and axle, inclined plane, wedge, pulley and lever. After we learned about simple machines we had to build one of our own. We didn't know how so we came up with ideas and tried to build them. We used Legos and K'nex to make the models. (Kathy)

I found out that a simple machine was a machine used to reduce effort and resistance force and make work easier. I learned about some simple machines that I did not even know were simple machines. I learned a screw was a simple machine. (Katie)

Work is using a force to move something. A simple machine is a basic, non-complex machine, without a motor, that makes work easier. (Jackie)
A simple machine is a machine that makes work easier by exerting effort over the resistance force. (Jay)

A simple machine is a machine that makes a job easier by reducing effort force needed to do work. (Tiffany)

We had to go back to the drawing board because our product took a motor to make it run but we only could use a simple machine. Our first idea was a rollercoaster but we couldn’t do that because it needed a motor so we stuck to our format but changed a few things around until we came out with a waterslide. This is like a rollercoaster but using gravity and momentum only. (Laverne)

I know that a simple machine is a device that makes work easier by changing the force and distance or by changing the direction of a force. (Marcy)
Part 5: Conclusions and Implications

Introduction

The purpose of this study was to determine if teacher modeling of metacognitive strategies, within a problem-based learning unit, would help students become independent, reflective thinkers. The results of the study clearly indicate that teacher modeling of metacognitive strategies, within a problem-based learning unit, increases student's self-directed learning behavior through adoption of these strategies. Therefore the study implies that students are becoming reflective thinkers since research establishes reflective thinking as the foundation of self-directed learning.

In this section I will discuss what the results of this study mean for classroom instruction. This discussion is organized around my three research questions. I will also outline future teacher-as-researcher plans for my own classroom.

Research Question One

Behaviors, Attitudes, and Beliefs

It is interesting to note that, as the students in this study became involved in the problem-based learning unit they became engaged at an emotional level. When asked to describe their feelings they used phrases like: I felt successful, I learned not to be worried, I made connections, this project was made for us and I chose to participate. Their perception that they were learning the way they wanted to learn increased their engagement in the
learning process. Students turned off by traditional teaching methods became active interested learners.

I have to speculate that the environment in which students are presented problem based information and strategies must play a crucial role in their adopting of metacognitive ways of thinking. When investment is high I believe this translates into greater motivation to learn. These positive classroom behaviors and beliefs imply that if a student feels empowered, believes he/she is in control and perceives that he/she has chosen to participate that motivation to learn will increase. Therefore from this study I conclude that creating a problem-based learning environment fosters positive student attitude. This positive student attitude is a major step in helping students develop into self-directed learners.

Metacognitive Strategies

This study implies that teacher-coaches can help students develop metacognitive strategies by modeling self-monitoring and evaluation processes, introducing strategies that students can use and modeling when particular strategies are useful and appropriate. In this study students were able to think through a problem using the teacher modeled metacognitive strategies of the need-to-know board process, mind mapping, prioritizing, and written personal reflections. This study also showed that in order for students to adopt these strategies they must be presented by the coach in a carefully planned process that allows the students to experience these strategies through a relevant, real life situation. Students will only adopt
these strategies if they see that they will help them reach a particular goal and that that goal must be important and relevant to them.

Student results from this study imply that teacher modeling of metacognitive strategies are essential for helping students develop strategies to solve ill-structured or real life problems. Throughout this study student conversations revealed that as students become aware of and begin to adopt these strategies they begin to develop the ability to:

- think about several different solutions using a process instead of immediately jumping to conclusions.
- confidently research complicated issues.
- cooperate and collaborate with peers.
- use many different types of resources to gather information
- choose appropriate strategies to complete the required task.

The development of these abilities implies that problem-based learning can help students learn to develop their thinking processes through a series of questions, learn to use various resources to think through a problem and learn to apply self monitoring, planning and evaluating strategies to solve a problem.

This research shows that modeling of metacognitive strategies helps students adopt these strategies as they solve an ill-structured problem. As discussed earlier it supports Vygotsky’s theory that “if a student receives
adult guidance or collaboration with a more advanced peer, that student can proceed to solve the problem and real learning is possible.” (Borich, 1996)

This was the first time students were introduced to these strategies. A great deal of modeling and direct instruction needed to occur for them to be able to practice these strategies. Therefore this study also supports Gallagher’s observation that “if students are going to internalize the habits of good question asking, information seeking, and reasoning skills then these skills will have to be practiced again and again.” (Gallagher, 1997, p.353)

This suggests that students must experience several problem-based learning situations before they can become expert self-directed learners.

Research Questions Two

This study showed a great deal of growth in the way students talked about or perceived their ability to solve problems. Students discussed how the different strategies they had learned (need-to-know, mind mapping, prioritizing, reflective journaling) helped them understand the topic better. Their comments showed a deeper level of learning. As one group of students discussed how they would solve a real life problem they actually made the jump from using the strategies modeled to describing how they would use a metacognitive strategy that had not yet been introduced to them. The strategy they described was a decision matrix. This implies that it is important to provide opportunities for students to communicate among themselves thereby allowing them to build upon each others ideas.
In this study student actions and reflections showed a growth in understanding the need to work cooperatively, share information, and develop creative solutions. In the beginning of this study most of the student participants did not exhibit these skills. I had to model these skills and coach them at appropriate times.

These skills are essential since problem-based learning requires ill-structured problems to be solved in teams and often requires innovative solutions, just as in real life. Groups usually do not function well naturally. Group communication and collaboration are learned skills. Therefore it is essential that these skills be modeled and practiced in the classroom. Acquiring these skills can only make problem-based learning more productive.

Research Question Three

This study indicates that teacher modeling and student adoption of metacognitive strategies help students acquire content knowledge. Students' ability to learn relevant content is directly effected by their awareness of metacognitive skills and development of positive attitudes toward learning.

In this study students were able to articulate how and why they solved their problems. They were able to discuss why they were able to produce quality work. This was in marked contrast to the Mission to Mars project completed just before the Fun House Challenge. The Mission to Mars project taught content first, using pre-selected labs, assigned readings, and multiple choice quizzes. A culminating problem was assigned after students completed
the labs and quizzes. It was obvious that there was very little student connection with this project. Barely 50 percent of the students turned in final projects and of these only five were good enough for the MAP Fair, and even these did not show much depth of understanding. During the focus group session Jay commented that "The experiments in the Mars project didn't help with the final project. I couldn't make any connections with it. But with the Fun House Challenge I learned ways to connect everything and it was interesting. It meant something."

The message seems clear – motivation and a feeling of engagement are crucial for student success – and with the success comes an increased responsibility for learning. Content skills and understandings are learned best when students can work with information rather than passively receive information. Content to them is important when they have a goal – a reason for knowing and understanding. This indicates that required content can be learned in the problem-based learning classroom. This environment allows students to explore the content domain in depth and not simply memorize facts.

Future Research Implications

I am committed to continuing this research. With this one brief unit I saw positive changes in my students, both in their thought process and their attitudes. There was a positive difference in the way they accepted their own responsibility for learning.
I believe that if the problem-based learning process is introduced early and continued throughout the year students will not only become aware of a thinking process but will begin to internalize this new way of thinking. Therefore I plan to implement three problem-based learning units during the year. While implementing these units I plan on paying attention to:

1. **Team building and collaborative skills.** My students seemed particularly weak in these areas. I will model these skills both before and during the PBL units. I will introduce these concepts through Project Adventure experiences and then tie them into the PBL units through modeling and reflections.

2. **Content acquisition.** I observed that many students had difficulty extracting content from written materials during their research. I will introduce the Literature Circle to students. I believe this is an appropriate metacognitive strategy that will help students gain a greater depth of content knowledge.

3. **Metacognitive strategies particularly useful in problem-based learning.** The strategies I will model and encourage students to adopt are need-to-know board, mind mapping, reflective journaling and if appropriate a decision matrix.

As I continue my implementation of problem-based learning I believe I will be modeling a "learner-centered classroom that honors students' voices and emphasizes students' making sense of things together." (McCombs and Whisler, p.31)
References


APPENDIX B

UNIT OF STUDY LESSON PLANS

BACKGROUND

In this PBL unit students will begin to develop into reflective thinkers by learning to use information in a logical, useful way. The process they will experience is the PBL Need-to-Know Board. The structure includes asking these questions:

1. What do we know?
2. What do we need to know?
   * List questions that must be answered to address missing information or shed light on a problem.
3. What should we do?
   * What actions do we need to perform?
   * What resources do we need to consult?
4. What did we do during the problem that was effective in solving the problem?

The instructor while encouraging students to adopt this process as a way to solve a problem will model this process.

The instructor provides opportunity for support and reflection on both the content learned and the learning process.

CONTENT

Students should know that people have depended on machines for thousands of years to make their lives easier and more enjoyable. Most machines are complex mechanical systems that are designed to perform some overall function. A complex mechanical system is made up of many subsystems composed of simple machines.

Students should know that engineers, architects, and others who engage in design and technology use scientific knowledge to solve practical problems. But they usually have to take human values and limitations into account as well.
General Content:

1. The main function of a machine is to make work easier. Machines can change the direction or amount of a force or the distance or speed of a force.
2. Energy is required to do work. Some objects have potential or stored energy because of their position. A moving object has kinetic energy because of its motion.
3. Machines transfer mechanical energy from one object to another. The amount of work done by a machine is always less than the amount of work put into the machines.
4. When a simple machine is used, an effort force is applied to the machine to overcome a resistance force.
5. A machine can be made more efficient by reducing friction.
6. Simple machines include levers, inclined planes, wedges, pulleys, wheel and axles, and screws.
Day 1 – April 25

At the end of class announce team assignments for the problem-based learning project. This will allow them time to accept the teams to which they have been assigned. Explain that the teams were assigned according to the strengths of individuals.

<table>
<thead>
<tr>
<th>Team 1</th>
<th>Team 2</th>
<th>Team 3</th>
<th>Team 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kelly</td>
<td>Katie</td>
<td>Kathy</td>
<td>March</td>
</tr>
<tr>
<td>Tiffany</td>
<td>Jackie</td>
<td>Kari</td>
<td>Alexis</td>
</tr>
<tr>
<td>Jim</td>
<td>Holly</td>
<td>Jill</td>
<td>Jay</td>
</tr>
<tr>
<td>Sack</td>
<td>Max</td>
<td>Ben</td>
<td>Cal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Team 5</th>
<th>Team 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jane</td>
<td>Leslie</td>
</tr>
<tr>
<td>Laverne</td>
<td>Chuck</td>
</tr>
<tr>
<td>Ned</td>
<td>Ralph</td>
</tr>
<tr>
<td>Tina</td>
<td>Anna</td>
</tr>
</tbody>
</table>

Teacher Observations
Students voiced objections to team assignments. I explained that they were going to have to work together to solve a problem and needed people with different strengths in each group. They agreed you need different people to look at a problem in different way but I can tell they still need time to think and accept the assignments.

For next year might have students take my Strengths Survey complete some of the Project Adventure team building activities.
Day 2 – April 27, 2000

Lesson Objectives
• Introduce the idea of problem solving by using a specific process.
• Introduce the idea of problem solving through the following strategies:
  1. Reflecting
  2. Monitoring Behavior
  3. Planning
  4. Communicating
  5. Identifying Alternatives
  6. Evaluating

Daily Plan
1. Ask students to write in problem log about a time they lost their keys.
2. Tell my story about losing my keys. Use overhead with cartoons to illustrate my story. As I progress through my story have Joanne put up problem solving strategy strips.
3. Have students revisit their experiences and label any strategies they think they used. Share with group.

Problem Log Entry
1. When I lost my keys some of my thoughts and actions were...
2. The processes I could use when trying to solve a problem are...
3. I was expected to...
4. I now know...

Teacher Observations
Only 12 students in attendance because of Take Your Child to Work Day.

Remaining students were very receptive. They assured me they could explain what they learned to the others.

Student seemed really engaged in my story. You could hear a pin drop – unusual for this talkative class.

They took time to fully write out a personal experience and connect strategies to their problem. They were eager to share their experiences.

Journal entries were thoughtful and complete.
Day 3 – May 1, 2000

Lesson Objectives
- Students will work in groups.
- Introduce the problem to the students.

Daily Plan
1. Students will first write in their problem logs. Ask students to take 5 minutes and reflect back on the last class by responding to the following questions:
   - One thing I learned about solving a problem is...
   - Something that really surprised me is...
   - A problem that I solved this weekend was...and the way I solved it was...
   Ask students to share their responses with the class.

2. Have students discuss in small groups the processes they learned on Thursday about solving problems. Those that were in class Thursday should review with those in their group that were absent. Students who were absent will report out to the entire class.

3. Introduce The Hook to the students.
   - Show first five minutes of Raiders of the Lost Ark and first five minutes of Flubber. Have students respond in problem logs to the question: What simple machines did you see being used in these video clips?
   - Students will share ideas with their group. Groups will share with entire class.

4. Introduce Problem Scenario to the students.
   - Hand out team folders to students. Read the Request for Proposal (RFP) aloud as students read own copy.
   - Give students time to discuss the RFP. Ask them to discuss: What do you need to do to solve the problem?
   - Briefly share the 4 steps in the PBL Process.

Problem Log Entry
1. One thing I learned today is...
2. A question I have is...
Day 3 (continued)

Teacher Observations

Students were eager to share initial problem log entries but did not want to listen to others. It worked better when they shared in small groups. Need to work on listening skills.

When I introduced the hook and asked them to record the simple machines they at first seemed puzzled but collectively came up with an extensive list. Lists in journals or when they offered an idea to the class usually started with “I’m not sure what a simple machine is but I think ...”

When given the problem scenario they became very engaged. Began relating experiences to each other. Students immediately wanted to suggest solutions when asked what they needed to solve the problem.

There were lots of how and what do I do questions when I introduced the PBL Process.

Almost every student asked in problem log “what is a simple machine”.

Note on Chuck: amazing change in attitude. He is on time, didn’t bring his bookbag with him and had all required tools. This is very different from the arguments I have had almost every class with him about being late, not bringing his book bag with him and forgetting his pens, pencils, homework etc.
Day 4 – May 3, 2000

Lesson Objectives

• Introduce PBL Process Steps 1: Ideas. Have students experience this step.
• Display PBL Process Steps on sheets of newsprint as they are introduced.
  Display sheets throughout unit. Titles to use are:
  1. Ideas – Possible solutions to problem.
  2. Facts – What we know.
  3. Learning Issues – What we need to know.
  4. Action Plan – How will you perform the research?

Daily Plan
1. Open discussion on the RFP.
2. Present in detail the PBL Process for solving a problem. Place one section up at a time. Describe the process for each.
3. Give each group large sheets of construction paper. Have them brainstorm Ideas. Have them share ideas with entire class.

Problem Log Entry
1. What would be a more efficient way to get all our ideas recorded?
2. In contributed or I arrived at my ideas by ...
3. Ask a question.

Teacher Observations
Everyone listened very intently as I introduced the PBL Process steps. Students dug into brainstorming. All groups were on task. In the beginning students looked to adults (Joanne was present) for advisement but as class went on they began to accept Joanne’s and my less prominent role. I think this happened because we kept throwing their questions back at them.

Groups 2, 4, 5, were good listeners among their small groups. They were piggybacking off each other’s ideas. Group 1 and 3 had problems listening among themselves. Seem to have interpersonal problems. Will work with them on this.

They had lots of ideas but again had trouble sharing in large group. Conversation continued within small groups when asked to share with the large group. Did not want to listen to one another. Need to work on whole group listening skills but this may not be the time for that. Will shift to working entirely in small groups. Generate ideas in writing on sheets.

Using students to facilitate large group sharing did not work. I had to step in.
Day 5 – May 5, 2000
Lesson Objectives
• Continue moving through PBL Process. Have students continue to experience each step.

Daily Plan
1. Post student Ideas. Discuss. Ask for student volunteer to type up and distribute Ideas sheet at next class. Ask for student volunteer to place ideas on construction paper.
2. Move to second part of the process – Facts. Discuss in small groups and then try a large group discussion. Record on newsprint. Ask for student volunteer to type up and distribute Facts.
3. If time allows begin Learning Issues.

Problem Log Entry
1. Summarize what we did today.
2. I arrived at my ideas by...
3. In my mind I began to see...
4. A questions I have is...

Teacher Observations
Except for group 6 students were totally engaged in tasks. Completed Ideas. Students wanted to discuss pros and cons. Joanne and I redirected them by reviewing brainstorming rules. Took more time finishing this up then I had planned. Was torn between giving more time and moving on. Gave more time because they were engaged and productive.

Temporarily solved problem of listening in large groups by having each group write ideas on their own poster and then display their poster. This worked well – groups were very engaged. They wrote clearly and in large print so posters were easy to read when posted.

Facts – When this process step students had to be prodded. Needed leading questions to begin this process. Finally referred back to RFP memorandum to complete list. Very few included personal knowledge.

With problem log entries had to review the meaning of summarize. Students were engaged in their writing.

As they left the class they kept talking about ideas and facts. Later in the day Jay, Ned, Laverne, and Tiffany came back later in the day and added ideas and facts.

I was surprised. Chuck volunteered to type all the lists. He came during Directed Study to do this. This is the first time he has volunteered.
Day 6 – May 9, 2000
Lesson Objectives
• Continue moving through PBL process. Have students continue to experience each step.

Daily Plan
2. Complete Learning Issues. Discuss in small group. Then in large group share ideas. Use a round robin to get all ideas listed on newsprint. Use two students to write ideas on newsprint.
4. Chuck will finish typing these lists.

Problem Log Entry
1. Summarize the PBL Process.
2. I contributed...
3. Some learning issues not listed are...
4. What I want to do next is...

Teacher Observations
Students were able to generate many learning issues. By using a round robin technique and moving quickly there was less of a listening problem.

While circulating and listening to the small groups I noticed students were referring back to facts when coming up with many of the learning issues.

When listing idea for action plan students need prodding to come up with ideas other than books.

While reading problem log entries I noticed most students were able to list the PBL process steps in their own words. They either listed them in their own words or quoted the subtitles (i.e. Learning Issues – what we need to know).

In response to the entry what I want to do next is...most students indicated they wanted to jump right into a solution. Many said they want to make a specific model. Indicates they have not connected the action plan (idea of needed to plan and research) to the learning issues.
Day 7 – May 11, 2000

Lesson Objectives
• Continue moving through PBL process.

Daily Plans
1. Students will review problem log entries. I included many questions in order to try and get them to connect learning issues and action plans.

2. Groups will draw up their action plan and begin research.

3. I have placed several resources on carts for them to use.

Problem Log Entry
1. My part in the research is...
2. Resources I will use are...

Teacher Observations
Students read my responses with interest.

Problem log entries were superficial. This is a departure from the thoughtful entries they have been writing.

Students seem less engaged and frustrated. They seem to have problems planning and making research connections.

I need to model a strategy they can use to move forward with their research. Perhaps – a mind map would be helpful.
Day 8 – May 1, 2000

Lesson Objectives
- Model a strategy for students that will show them how to move forward with their research. Strategy to model is mind mapping.

Daily Plans
1. Ask students if they have ever done any mind mapping. Show them a teacher example in the form of a web.

2. Have large sheets of construction paper placed around the room, one site per team. Each person in a group is given a marker. Groups are instructed to take learning issues and create a mind map. Learning issues are to be broken down into common clusters.

3. Students present their mind maps. Discussion to revolve around the following questions:
   - How did you group the learning issues?
   - Why did you place individual issues in specific groups?
   - Which group should you research first? Why?

Problem Log Entry
1. How and why should you prioritize learning issues before beginning research?

Teacher Observations
Mind mapping activity took most of the class but it was worth it. Discussion that followed went well. Most listened to what others were saying. Some even took notes.

Mind map showed a consensus among the different groups. Students were able to voice why they grouped different issues together. The group came to a consensus that the simple machine issue was the first cluster that needed to be researched.

Comment was made that one step would lead to another.

All were engaged and took part in the activity.

After reading the problem log entry I can say – They got it!
Day 9 – May 17, 2000

Lesson Objectives
• Embedded instruction: present some direct instruction in the form of focus questions and a video.

Daily Plans
1. As a large group students prioritize the simple machines learning issues cluster. Students record prioritized list in their problem log.

2. Give students a handout of focus questions. Explain that it can be used to organize their notes as they watch the video on simple machines or it can be used to guide them in their research. Emphasize this is for their use and will not be handed in for a grade.

3. Show video (20 minutes) on simple machines.

Problem Log Entry
1. Why did we develop a learning issues mind map?
2. Why did we decide to research the simple machines cluster first?
3. Why did we prioritize the simple machines learning issues before beginning research?
4. How does prioritizing help before you begin your action plan?
5. What help do you need in order to start your research?

Teacher Observations
Students were quickly able to prioritize the list and most agreed on the order or prioritization.

As they watched the video students were engaged. Some students asked to have portions of the taped stopped and played over. Two students asked to come in after school to watch it again. Comment: there is too much information to understand by watching it just once.

Problem log entries were very extensive. Entries indicate they were able to connect the information to the problem.
Day 10 – May 19, 2000

Lesson Objectives
• Students will develop a lesson plan and begin their research.

Daily Plan
1. Using mind map and prioritized simple machines cluster outline each team will develop a research plan and begin research. Students will need to work together and record plan in their problem log.

2. Students revisit original ideas and connect research to a possible solution.

Problem Log Entry
1. Reminder: include research plan and notes in problem log.
2. What simple machine(s) would support your idea(s)?

Teacher Observations
As I moved from group to group I heard intense discussion. Students were dividing up tasks. In two of the groups I heard the comment that it was important for everyone to do their job since they needed an answer to one question before they could answer the other questions.

I saw several students using the focus questions to organize their research.

Some students asked about the availability of kits. They wanted to build models to see how a certain simple machine worked.

Heard some reevaluating their ideas.
Day 11 – May 31, 2000

Lesson Objectives
• Students will continue their research.

Daily Plan
1. Students continue their research.
2. Legos, Boston Museum Simple Machine Kits, and K'nex are available for those that want to test out ideas.

Problem Log
1. Summarize your research up to this point in time.
2. I think this research will help us...

Teacher Observations
I have to be at a workshop at the University of Rochester. I stayed to start students working and then Joanne Bell took over.

Joanne commented it was difficult to get them started. We felt this was because there had just been a full week's interruption of classes. Students (except for four) had just returned from the New York City field trip.
Day 12 – June 2, 2000

Lesson Objectives
• Students will be presented with Presentation Guidelines.
• Students will continue their research.

Daily Plans
1. Handout presentation guidelines. Discuss and answer questions.

2. Students continue to research and/or begin working on final presentation.

3. Students are reminded that their final presentation is due June 12.

Problem Log Entry
1. Summarize the RFP (what is the problem?).
2. Discuss "What I know now that I didn’t know when I started."
3. The design or idea we will present as our solution to the problem is...
4. Here is how we will present our solution...

Teacher Observations
The pressure is on – some students seem on schedule, others are scrambling but at least they all seem to be moving in the right direction.

Several students stayed after school to work on project.

Problem log entries were very interesting. Most were able to summarize the problem correctly.

In answering what I know now that I didn’t know when I started students discussed not only the content they had learned but also the problem solving process and PBL steps.
Day 13 – June 6, 2000

Lesson Objectives
• Students will work on presentation/final project.

Daily Plan
1. Students work on final presentation/final project.
2. Students are reminded that this is the last class before they give their presentation.

Problem Log Entry
1. How confident are you about your team's presentation? Why?
2. Will you be ready to present your part? Explain.
3. Do you have any last minute questions or needs?

Teacher Observations

There was no class on June 9 because the students went to Seabreeze. Amazingly several students stayed after school to work on their presentations. I can’t believe they were willing to stay after being at Seabreeze all day. They stayed until 4:30 p.m. Some took supplies home with them.
Problem 14  June 12, 2000

Lesson Objectives
• Students will give final presentations.
• Students will receive feedback from judges.

Daily Plans
1. Students give final presentations to 3 judges: VP of Curriculum, House Administrator and IMYP Coordinator.
2. Presentations will be video taped.
3. Students receive feedback from judges via scoring sheets. Students discuss feedback.

Teacher Observations.

There was not a good place to videotape. Camera malfunctioned. In order to videotape another person is needed with a mobile camera.

Everyone was present. Often when presentations are given several students are absent. Students need practice in speaking in front of groups.

Most students were able to discuss their plans using correct vocabulary and concepts. Most students were able to answer judges’ questions.

Two groups were excellent. They had creative ideas. Visuals added to their presentations. They were well prepared to explain their ideas and answer judges’ questions. They had good presentation skills.

Three groups gave middle of the road presentations. Ideas were creative and could explain how and why ideas worked. Had poor presentation skills and no visuals except for the models.

One group was not prepared at all. It was obvious they had done little planning of the presentation. Their problem logs showed they had good ideas and extensive research notes. I think if there had not been such a gap between the last class and presentation date I would have been able to help them develop their presentation.
Day 15 – June 16, 2000

Summary

1. During final exam students will answer several content questions (multiple choice) on simple machines.

2. At the end of the final exam (put not part of it) students will complete a summative reflection entitled Think Back.

3. After the final exam nine students will meet with me for a group interview. The nine students that will participate are from each of the six teams. They are:

   Kelly  Tiffany
   Holly  Jane
   Kari   Leslie
   Laverne Sack
   Jay

Teacher Observations

Responses from the summative reflections were amazing. The students’ answers were in-depth and insightful. Reflections showed they had made connections between the idea of thinking through a process to solve a problem. They identified several useful strategies: mind map, prioritizing, problem log entries, focus questions. They wrote about learning more about cooperating and teamwork. These responses will be very useful data.

The focus group was very informative. Student comments showed an awareness of metacognitive strategies. They talked a lot about the importance of ownership. These responses will be very useful data.
TO: MAP 7 SCIENCE STUDENTS
FROM: Lynn Panton
RE: Request for Proposals: Fun House Challenge

DATE: May 1, 2000
MCNAIR HOUSE
Science Instructor

Even though it is not yet the end of the school year planning has already started for next year. One of our challenges is finding new and different ways to raise money for field trips. Many people have indicated they want alternatives to selling merchandise.

I have an idea for raising money – a Fall Fun Day. I need your help in creating a plan. Your challenge is to design some activities for this “fun” house that will be run by one or more simple machines. Be inventive! Be creative!

You have three weeks to meet the challenge. At that time you will present your proposal to Ms. Colicchio, McNair House Administrator, Mrs. Weed, IMYP Coordinator and Mrs. Sullivan, Vice Principal. It is important to convince them that this is a realistic idea. Since they are not scientists you will need to be very clear in explaining your idea. Therefore in your proposal presentation you must:

- Give a scientific explanation on how your device works.
- Show how your device can be constructed.
- Specifically list the materials you will need.
- Estimate costs.
- Explain why you think people will pay to use your device.
APPENDIX D

Focus Questions For Simple Machines

1. What is a simple machine?
2. How do simple machines help us do work?
3. What is the definition of work?
4. What is the definition of force?
5. What is the scientific formula for work?
6. In order to get work done what forces must be overcome?
7. What is the difference between effort force and resistance force?
8. What are two common types of resistance force?
9. What type of simple machine can be used to reduce the resistance force of friction?
10. What is a lever? How can you move a rock with a lever?
11. What is a mechanical advantage? How do machines increase mechanical advantage?
12. How can mechanical advantage be calculated?
13. What is a fulcrum? How does the position of the fulcrum change the mechanical advantage?
14. What is a wheel and axle? How does it work as a simple machine?
15. What is a pulley?
16. How do inclined planes work? Are they always fixed or do they move?
17. What is a wedge? How can a wedge help us do work?
18. What is a screw? How does a screw decrease force by increasing distance?
19. What is the importance of machines in work?
20. How will the above information help you find a solution to your Fun House Challenge? How will you use the above information in your final Fun House Challenge presentation?
## APPENDIX E

### Problem Log Reflective Questions

| Day 2 | 1. When I lost my keys some of my thoughts and actions were...  
2. The processes I could use when trying to solve a problem are...  
3. I was expected to...  
4. I now know... |
|-------|--------------------------------------------------------------|
| Day 3 | 1. One thing I learned today is...  
2. A question I have is... |
| Day 4 | 1. What would be a more efficient way to get all our ideas recorded?  
2. I contributed or I arrived at my ideas by...  
3. A question I have is... |
| Day 5 | 1. Summarize what you did today.  
2. I arrived at my ideas by...  
3. In my mind I began to see...  
4. A question I have is... |
| Day 6 | 1. Summarize the PBL Process.  
2. Today I contributed...  
3. Some learning issues not listed are...  
4. What I want to do next is... |
| Day 7 | 1. My part in the research is to...  
2. Resources I will use are... |
| Day 8 | 1. How did your team group the learning issues?  
2. Why did your team place individual issues in specific groups?  
3. Which group should you research first? Why? |
| Day 9 | 1. Why did your team develop a learning issues mind map?  
2. Why did your team decide to research the simple machines cluster first?  
3. Why did your team prioritize the simple machine learning issues before beginning the research?  
4. How does prioritizing help before you begin to develop your action plan?  
5. What help do you need in order to start your research? |
| Day 10 | 1. Summarize the progress of your research.  
2. What simple machine(s) would support your idea(s)? |
| Day 11 | 1. Finish summarizing your research.  
2. I think this research will help our team... |
| Day 12 | 1. Summarize the original RFP.  
2. What do you know now that you didn’t know when you started?  
3. The design or idea our team will present as our solution to the problem is...  
4. We will present our solution by... |
| Day 13 | 1. How confident are you about your team’s presentation? Why?  
2. Will you be ready to present your part of the presentation? Explain why or why not.  
3. Do you have any last minute questions or needs? |
| Day 14 | 1. How did you feel when you were giving your presentation?  
2. What would you do differently? |
| Day 15 | 1. Think Back! |
### Problem Log Rubric

<table>
<thead>
<tr>
<th>Little Evidence of Thoughtfulness</th>
<th>Some Evidence of Thoughtfulness</th>
<th>Strong Evidence of Thoughtfulness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited Response</td>
<td>Response Supported by Specific Examples</td>
<td>Response Supported by Examples and Personal Reflections</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Thoughtfulness =
- Originality
- Creativity
- Evidence of Higher Order Thinking
- Makes Connections
- Personal Reflections
A good place to keep this information is in your problem log.

1. Revisit the RFP and summarize the problem.

2. Revisit the What Your Know List and your current research and state what you know now that you did not know when you started.

3. Revisit the Possible Solutions list.

4. Choose the activity you think will best solve this challenge and commit to it. Write it down in your problem log.

5. Plan your presentation. Outline the information you will include in your presentation and describe how you will give your presentation. Remember this is a team presentation.

6. In your presentation be sure and include:
   - A description of the device.
   - A discussion of why you think it is a realistic solution.
   - The scientific description of how the device works.
   - A description of how it will be constructed.
   - Estimate materials and cost.

7. When developing your presentation remember the judges will be asked to evaluate your team on the following:
   - Is this a realistic idea?
   - Can you help the judges as non-scientists understand how the device will work?
   - Do you (the judge) think the students can build this device and actually use it to raise money?
   - From the student presentations can you easily visualize how the device will look and work?
   - Could you easily hear and understand the group?
   - Did the visuals add to the presentation?
   - What is your recommendation: Proceed or Go Back to the Drawing Board.
APPENDIX H

PRESENTATION RUBRIC
FOR
FUN HOUSE CHALLENGE

Group Number:  
Group Names:  

As a non-scientist do you understand how this device works?
0 1 2 3 4 5

From the students’ presentation can you visualize how the device will look and work?
0 1 2 3 4 5

Is this a realistic idea? Do you think the students can build this device (with further planning) and actually use it to raise money?
0 1 2 3 4 5

Could you hear and understand the group?
0 1 2 3 4 5

Were the visuals the group used helpful in understanding their idea?
0 1 2 3 4 5

Recommendation: Go Forward with the Idea
Go Back to the Drawing Board

Comments: