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ABSTRACT

Problem-based learning (PBL), often used in medical education, is an educational approach that organizes curriculum and instruction around carefully crafted "ill-structured" problems, to which students apply knowledge from multiple disciplines and critical thinking. PBL is being investigated as a teaching approach for elementary and middle schools. Its use was evaluated in three classrooms in two schools, at combined first and second grade levels, combined third and fourth grade levels, and eighth grade levels. Preliminary qualitative data have been gathered through classroom observation, semistructured interviews, and review of student-generated and classroom records. Brief case studies from each of the classrooms illustrate PBL in action at the K-8 level. Preliminary ideas for the further study of PBL are emerging, beginning with the question of whether ill-structured problems are appropriate for young students, and if so, how should they be developed? The implementation of PBL in the elementary and middle school classroom is, of necessity, very different from its implementation in medical school, and its success may rest on the careful identification of the outcomes to be desired or expected. Appendix A is an instructional template for a PBL unit, and Appendix B is a list of resource persons and organizations. (Contains 3 unnumbered tables and 23 references.) (SLD)

A Qualitative Examination of Problem-Based Learning at the K-8 Level: Preliminary Findings

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Introduction

There is currently a call for reform in virtually every area of education in this nation. Educators criticize the disconnectedness of traditonal mimetic instruction and advocate for more authentic teaching, learning and assessment; that is, providing the opportunity for students to work on real-world problems and issues to provide a more authentic context for learning and for assessing learning. Various professional organizations and groups (see in science, for example, the National Research Council's *National Science Education Standards*, 1996, and the American Association for the Advancement of Science's *Benchmarks for Science Literacy*, 1993) are defining curriculum standards and desired learning outcomes within a more constructivist framework (Brooks & Brooks, 1993) which suggests posing relevant problems to learners and structuring learning around primary concepts. Other groups (for example, U.S. Department of Labor's SCANS Report, 1991) define the need for competence in not only basic skills and personal qualities but also thinking skills, such as solving problems, reasoning, and knowing how to learn, for solid work performance.

Many of the classroom teachers with whom I work in my capacity as research specialist for problem-based learning at the Illinois Mathematics and Science Academy have personally come to the same conclusions about what is best for the students in their classrooms. They are seeking curriculum and instructional strategies that exemplify the above outcomes of active learning, problem solving, thinking skills, and authenticity. One such strategy we and they believe has great promise for contributing toward these outcomes is **problem-based learning** (PBL).

PBL has a history of over two decades in medical education. In this field, PBL is defined as follows (Barrows & Tamblyn, 1980):

> . . . the learning that results from the process of working toward the understanding or resolution of a problem . . . encountered first in the learning process [that] serves as a focus or stimulus for the application of problem-solving or reasoning skills . . . In this approach, the student takes on a patient problem, a health delivery problem, or a research problem as a stimulus for learning . . . This method of learning has two educational objectives: the acquisition of an integrated body of knowledge related to the problem, and the development or application of problem-solving skills (pp. 14, 18)

PBL has only more recently (the past 5-7 years) been implemented in K-12 educational settings. The Center for Problem-Based Learning, established at the Illinois Mathematics and Science Academy (IMSA) in 1993, defines PBL (1995a) as:

> . . . an educational approach that organizes curriculum and instruction around carefully crafted "ill-structured" problems. Students gather and apply knowledge from multiple disciplines in their quest for solutions. Guided by teachers trained as cognitive coaches, they develop critical thinking, problem solving, and collaborative skills as they identify problems, formulate

hypothese, conduct data searches, perform experiments, formulate solutions and determine the best "fit" of solutions to the conditions of the problem. Problem-based learning enables students to embrace complexity, find relevance and joy in learning, and enhance their capacity for creative and responsible real-world problem-solving.

(For more information about the Center for Problem-Based Learning, see Appendix B.)

One example of an ill-structured (messy and complex; changing and tentative; no simple, fixed, formulaic solution) problem scenario is:

- *You are a scientist at the state department of nuclear safety. Some people in a small community feel their health is at risk because a company keeps thorium piled above ground at one of their plants. What action, if any, should be taken?* (IMSA, 1992, Summer Challenge enrichment program for 7th and 8th grade minority students)

PBL is distinguished from other instructional approaches such as the case method or discovery learning in that PBL **begins** with the introduction of an ill-structured problem on which all learning **centers**. Students are not introduced to the problem as the culminating activity of a more traditional unit nor are they expected to play the guessing game of, "What's the right answer the teacher wants me to find?" (Center for Problem-Based Learning, 1995b). A description of the critical teaching and learning events in PBL are found in Appendix A.

Purpose

Much has been written about PBL and its effects on learning at the medical school level and a growing literature is developing on PBL at the secondary (high school) level (Barrows & Myers, 1993; Gallagher, Stepien & Rosenthal, 1992; Gallagher, Stepien, Sher & Workman, 1995; Savoie & Hughes, 1994; Stepien, Gallagher & Workman, 1993; West, 1992). Few, if any, articles or reports focus on using PBL in elementary and middle school classrooms. Yet we are working with a number of teachers at these levels who believe PBL to be very workable, highly engaging, and successful for their students.

The primary purpose of this study, and the focus of this paper, is to **describe the characteristics of PBL** as a curriculum development and instructional strategy at the K-8 level. A secondary purpose is to describe the **effects of PBL upon students' learning**, particularly in the areas of content and of thinking skills.

Methodology

For research sites, I identified **three classrooms in two schools** from a potential pool of schools who had been in some sustained relationship with the Center for Problem-Based Learning for at least two years. I wanted sites in which PBL was not in the very earliest stages of implementation and also ones in the

Chicago area so that I would be able to be a frequent participant observer without incurring long-distance travel costs.

One site is a **suburban elementary school** in the Chicago area in which PBL is being disseminated throughout the building. The two teachers who participated in this building, one a **1st/2nd grade teacher and** the other **a 3rd/4th grade teacher,** are both in their second year of implementing PBL in their classrooms. The other site is a **suburban middle school** in the Chicago area in which the teachers selected are also in the second year of using PBL (they are the only ones in their building using PBL consistently). The **two teachers, one science and one language arts,** were **team-teaching** by combining their two **8th-grade classes** in a double period and were using PBL almost exclusively to teach science content as well as to incorporate language arts. I was present for data collection in these sites (usually 2-3 times per week) from September, 1995 - February, 1996 for any PBL units during those times (2 problems in the 8th grade class and the 1st/2nd grade class, and 1 problem in the 3rd/4th grade class)

To match the purpose of describing PBL and its effects, I selected a primarily qualitative methodology, including:

- classroom observations (usually videotaped) during identified critical teaching and learning events in PBL (see Appendix A)
- semi-structured interviews with a small group of 4-5 students from each class (purposely identified by teachers for diversity of gender and learning style and, in the multi-age classes, of grade level) before, during and after their PBL experience(s)
- semi-structured interviews with the teacher(s) from each class before, during, and after the PBL experience(s)
- collection of student work during the PBL experience(s), particularly student logs
- collection of other artifacts related to the PBL experience(s), including notes to parents, media articles, identified curriculum outcomes, etc.
- teacher reflections throughout the PBL experience, captured by the teachers' self-recording of thoughts and by my field notes of informal conversations
- focus group interview with the teachers and with student and parent volunteers (not yet completed)

I am currently in the process of analyzing this qualitative data, with my preliminary findings given in this paper. I plan to incorporate my initial open coding scheme (Strauss & Corbin, 1990) into a more rigorous analysis using Q.S.R. N.U.D.I.S.T qualitative data analysis software, Mac Version 3.0.5, to explore and link ideas and construct grounded theories about the data. I plan to develop richer and more interpretive case studies (Lincoln & Guba, 1985) to provide a thick description of PBL in these particular settings when I complete this more thorough data analysis.

I added a quantitative component, pre- and post-testing students for basic content knowledge, for the purpose of piloting appropriate ways to assess K-8 students' content acquisition in PBL and in non-PBL classrooms. While comparable content acquisition in PBL and traditional classes has been well-documented in medical school literature, it has not been in K-12 classes. However, one of the first questions asked by parents and administrators is: Do students learn at least the same amount of basic content in PBL classes as in non-PBL classes?

In a limited attempt to examine this content issue, I asked the teachers to develop a paper and pencil test, assessing the content covered in the first PBL unit in each class, that was administered to their PBL classes as well as to one control class matched to each PBL class. Because a final post-test will be administered in May, 1996, results from this portion of the study are not yet available.

PBL in Three Classrooms

I am sketching brief case studies of each of the three classrooms in which I collected data, primarily to outline the teaching, learning, and assessment events that occurred in the first PBL unit each teacher did during the 1995-96 school year. The first two (elementary) classrooms are both located in Northfield Elementary*, a suburban school with 560 students in which PBL is promoted in the building by a team including the former principal, now a district consultant, and several teachers experienced in PBL. The school consists of about half multi-age classes and half single grade classes. In this building, many teachers use PBL as a strategy two or three times during the school year, with each PBL experience taking approximately 4 weeks (about 1 hour per day). These teachers were trained in PBL by the former principal and other staff members in the building who came to the Center for Problem-Based Learning's annual Harris Institute for the Introduction to PBL (see Appendix B) as well as participated in a year-long partnership with the Center. They use a hybrid of the model of PBL developed by the Center for Problem-Based Learning (Appendix A) and of a model more closely paralleling the medical school model, described by Barrows and Myers (1993). The third class setting, at suburban Ellsworth Middle School, is comprised of a science class and a language arts class for 8th graders in which the two teachers use PBL almost exclusively with the combined two classes over the course of the school year. These two teachers attended the introductory Harris Institute as well as an advanced Institute and also participated in a year-long partnership with the Center. They use the Center for Problem-Based Learning's model of PBL (Appendix A).

PBL in Carol's* 1st/2nd Grade Class at Northfield Elementary: The Plant Problem

Carol, an experienced primary teacher, is a real believer in the power of PBL with her students because of her experiences with PBL last year. She implemented two problems in her class last year, one centered around helping an impoverished local family at Thanksgiving, and the other around helping her daughter decide whether or not to take the family dog along to college. In both cases she saw her students doing complex thinking and problem solving often thought to be "impossible" for such young children. A number of Carol's "old friends" (2nd graders) this year were in her class last year and so had already experienced PBL. This year, the first problem she ran in her class of 23 (in September and October) was created by a PBL "design team" formed in the district. It involved an authentic situation: the failure of the former building principal's newly planted flower garden to thrive over the summer.

* pseudonyms are used for the actual names of schools and teachers

Carol prepared her class for this science-oriented PBL experience early in September by conducting several plant experiments, including one documenting how food coloring was absorbed into a stalk of celery. She also used the KWL strategy (What do you think you *Know*? What do you *Want* to know? What have you *Learned*?) to introduce her students to concepts about water and how it is used in plants and compiled a collection of library books about plants and related issues. However, her students did not know about the PBL experience until their former principal, Dr. Irene Thompson, came to their class one Wednesday in mid-September to help them **meet the problem**. Irene described how she had planted a number of plants in her garden in the spring, many of which were now drooping and losing leaves. She made it clear that some of her **conditions** in solving the problem satisfactorily included no harm to the environment or to animal life around her house, as well as low cost. Irene then asked the students--already chiming in with questions and suggestions--if they would be willing to help her solve her problem, and they enthusiastically said "Yes!"

Carol and Irene then led the students through the next stage in their district's model of PBL, **framing the problem**. The problem "frame", an adaptation of the frame suggested by Barrows and Myers (1993), consists of a large strip of butcher paper divided in four color-coded segments:

Problem Statement: Dr. T.'s plants are dying and she needs help, but she doesn't want animals to be hurt when we help.

IDEAS	FACTS	LEARNING FACTS	ACTION PLACES
(possible solution ideas) <u>Sample responses</u>: • have 2 gardens--one for animals to eat, one for Dr. T. to enjoy • add earthworms to the garden • pull out weeds	(facts students know) <u>Sample responses</u>: • some plants need light and some don't • roots hold plants in the ground • diatenacious dirt can kill earwigs	(questions students have) <u>Sample responses</u>: • how far apart should we plant seeds? • are insects good for plants? • are there birds eating the plants?	(possibilities for gathering information) <u>Sample responses</u>: • field trip to Dr. T.'s house • go to plant store • ask moms, dads, grandparents • library

For about 40 minutes, the majority of the students in the class were actively engaged in suggesting items to put in the problem frame. First, the facilitators encouraged students to define the problem through developing the **problem statement.** Both facilitators (Carol and Irene) found their coaching skills (particularly questioning strategies) to be critically important in helping students bring out their prior knowledge, distinguish fact from opinion, and probe more deeply for knowledge and ideas. Irene probed students on several issues: "I don't get it; how do weeds kill my plants? How do you know that is a fact, Brian?"

When students began running out of ideas and became restless, the facilitators checked again for the accuracy of the problem statement. When students agreed, Irene left. Carol asked her students if they would **accept the problem** and commit to helping Dr. T. She also asked them to think about determining topics for small groups to work on in **gathering information** over the next several weeks, and affirmed the students for all they already knew about plants.

The next day, Carol's students again worked on the plant problem for about an hour. They reviewed the problem statement, and then looked for ways to group the learning issues/facts so that small groups could tackle gathering information on a particular issue. Carol collapsed student suggestions and her own into the following six groups for gathering information: **(1) seeds; (2) bees, birds, animals; (3) insects; (4) earthworms; (5) plants and weeds; (6) dirt**. Students volunteered to join a particular group, and Carol recorded their names. During the process of determining groups, students raised the issue of including a 2nd-grader in each group because "they know more and they can write better." Carol had mentioned to me that some 1st-graders had already raised issues of uncertainty in doing some of the work on their own, so she led a brief discussion on possible ways to work, including using and drawing pictures, writing just the name of something, and tape-recording information or finding a video to watch.

Students then met in their groups to work on learning facts from their topic. Carol made a basket containing sticky notes labeled "problem facts" available to students. Through the course of information gathering, when students found out facts about their topic, they wrote the facts on sticky notes and put them up in the appropriate place on another large sheet of butcher paper labeled with the six group names. Some students' fact notes included words and pictures, some just one or the other. I observed the "Seeds" small group while Carol circulated among all the groups. Amy, a 2nd-grader, found an illustration contrasting properly placed seeds with crowded seeds, but did not read the text below that explained the illustration, and could not tell me why the two pictures were different. As this early stage of information gathering, most students did not focus on what information would be of most use to their group but seemed to skim the surface of many different materials, including books, computer resources, etc.

Over the next ten days (continuing to focus on PBL information gathering for about an hour 4 or 5 times a week), Carol's students became more focused on what information they needed as they began talking with other groups, getting more information at school as well as on their own time at home, and watching the results of several plant experiments they asked Carol to help them set up. In their experiments, the students explored variables such as light, water, and dirt to determine their effects on plant growth. Students, in one experiment, asked for a sample of dirt from Irene's garden and brought in a sample of dirt from a student's healthy garden and planted seeds in each. Throughout this information gathering period, Carol continued to focus students on their problem statement and supported them in their work through embedded lessons on telephone skills, letter writing, and use of the computer. Students were also heavily supported in their research--particularly involving information from online encyclopedias or Internet resources--in the school library by the library/media specialist, who is very involved in the district's efforts in using PBL, and other library personnel. Carol also incorporated language arts, drama, and math activities about plants throughout the rest of her daily schedule.

Early in October, Carol began to wrap up information gathering and guided students toward planning their **presentations** (recommendations) to Dr. Thompson. She coordinated lessons with the art teacher (to help develop visuals for the presentation) and the library/media specialist (to help with computer applications including creating headings and graphics, although most students did not choose to use computer applications in developing visuals) to help students prepare presentation materials. She gave them the choice of developing "backboards" or overhead transparencies for presenting visual information to Dr. Thompson. The previous six research groups re-combined into five presentation groups: **(1) animals (including birds, bees and insects); (2) earthworms/dirt; (3) plants and weeds; and (4/5) seeds.**

The next week, as students began to work in their new small groups, Carol again went over their class rules for small group work, particularly to "be responsible" for all group members getting their respective jobs done. They discussed criteria for "good" presentations, including making the presentations understandable, attractive, and concise. Carol provided time over about five school days for the groups to prepare their presentations.

Dr. Thompson was unable to be present the day of the final presentations because of a family emergency, so I copied the videotape I made to give to her. Group 1, Dirt, used overheads to tell a story, *The Poor Plant Who Had Too Much Clay*, and explained Dr. T. needed to put topsoil over the 8 inches of clay in her garden (information obtained from her soil samples and from an actual soil survey of area). They also created a backboard displaying a diagram of this ideal soil arrangement and of Dr. T.'s plants. Finally, they performed a rap about soil. Group 2, Animals, used a backboard full of printed material, and group members took turns reading parts to their classmates. They also had drawn diagrams to represent "good" and "bad" animals for the garden, focusing in particular on the helpful role of bees. Group 3, Plants, used a series of overheads to detail conditions necessary for healthy plants, including sunlight, water and food. They also discussed proper depth and spacing of seeds and the importance of weed control. Group 4, Seeds, created a backboard displaying a graph representing seed growth. They also displayed diagrams showing the steps of seed/plant growth and discussed proper planting techniques. Group 5, another Seed group, had worked with Carol to develop flip books showing seed growth. They also displayed a story they had dictated to her:

> We are the seed group. We got information to help your garden grow better. This is what we know. It starts out as a seed, then it sprouts and you see roots. After that it grows a stem and then it grows a leaf. The seed grows into a flower. We found out that seeds have food in them. Seeds need sun, water and air to grow.

To summarize this PBL experience in Carol's class: students worked about an hour per day, four or five days a week, for four weeks to define, research, solve, and present findings regarding their former principal's unhealthy plant problem. Throughout the process Carol kept students focused on their problem statement to guide their efforts and provided a number of active learning opportunities. By using this problem as a context, the students accomplished the following science objectives:

- What do plants need to grow?
- How does a plant grow and develop? What are the stages of a plant's life cycle?
- What do the different parts of a plant do?
- What factors affect seed germination?
- What effect does the type of soil have on plant growth?

In a parent newsletter, Carol reported:

> By engaging the students in realistic problem scenarios, I can reinforce the basic skills I am teaching by putting a purpose behind them. A skill that is used for a reason will be remembered, while one presented without purpose will not. My goal is for my students not to ask why they have to learn something or "when will we ever need to know this?"

Carol assessed student work during the problem with writing prompts, the ongoing group "facts" chart, a mini-book on plants, an assessment on parts of plants, and at the end of the problem through their actual recommendations to Dr. Thompson. She reported results through narrative comments on report cards and several parent newsletters.

The students, in a debriefing session after their presentations, made comments like:

- I thought our presentations were a lot better than last year because of the overheads and backboards.
- This is the best problem I ever worked on because we didn't just talk about plants; we talked about water, too.
- I don't like problem solving very much because I have to work with other people. I like working at my own pace.
- I like it because you can draw and make things.
- I liked it because we were helping Dr. Thompson.
- The third graders are working on this problem, too - could we share our solutions (video) with them?

<u>PBL in Jennifer's 3rd/4th Grade Class at Northfield Elementary: The Plant Problem</u>

Jennifer is a younger teacher with strong, well-developed ideals about constructivist teaching and learning practices and authentic assessment. She facilitated several PBL units in her class last year and, like Carol, had some of those same students back this year. Jennifer typically uses the phrase "integrated studies" to describe her students' work in the problem rather than the term "PBL". Jennifer's students also worked through the same plant problem, also beginning in mid-September, as in Carol's class. However, they **met the problem** through a letter from Dr. Thompson, asking for students' assistance with the problems in her garden and the conditions under which she was willing to solve the problem. Her students from last year instantly recognized this letter as a prompt for PBL and said so.

Jennifer then facilitated the **framing of the problem**, and students developed the following frame (again, as suggested by Barrows & Myers, 1993):

Problem Statement: To find out how we'll make the plants grow healthy.

IDEAS	FACTS	LEARNING ISSUES	ACTION PLAN
(possible solution ideas) Sample responses: • build a fence around the garden • use a greenhouse • have a Venus Flytrap • use removable pieces of wood and plastic to protect plants from animals	(facts students know) Sample responses: • some flowers don't have leaves • Dr. T. doesn't want to harm environment • the parts of a plant include stem, petals, leaves, stamen, pistil	(questions students have) Sample responses: • how much water do certain plants need? • where is her garden located? (e.g., shade/sun, etc.) • what kinds of plants are in her garden?	(possibilities for gathering information) Sample responses: • bring two parents in to speak about their healthy gardens • field trip to Dr. T.'s house

Students copied the problem frame on a blank problem frame template paper, which was incorporated the next day into their *integrated log*, an ongoing documentation of each student's work in the PBL experience. During the first several days of researching the problem, Jennifer added items as students suggested them to each column on the laminated (and so erasable) problem frame template she kept posted in the room.

As compared to Carol's class, Jennifer's students were quicker to jump to conclusions about what was causing the problem and thus what the solution was. Their first idea, as suggested by one student and immediately adopted by many others, was that animals were eating the leaves off Dr. T.'s plants. Several days later, another student suggested that the roots were growing together which made them "snap". The "roots snapping" (mis)conception was very prevalent throughout the information gathering phase of the problem until students examined fibrous and tap roots and specifically discussed whether or not roots actually snap. When the first frost of the season occurred during work on this problem, one 4th-grader suggested that there was no point in going to see Dr. T.'s garden now because all the plants would be dead. This also raised a number of issues around students' understanding of the concepts of annuals, biannuals, and perennials.

The day after framing the problem, Jennifer organized students into self-selected groups to inquire about the following topics: **(1) water; (2) kinds of plants; (3) cost; (4) fertilizer; and (5) animals**. For about two weeks, for 30-60 minutes about 4 days a week, students in these small groups **gathered information**, relying most heavily on phone calls to local nurseries and stores and on books from the school library. One day Dr. Thompson came to the class for a question and answer period in which the students asked for specific information about what plants she had, how she was caring for them, and what the growing conditions in her yard were. Students from last year's class led a re-enactment of a skit they had developed about the photosynthesis process. Other students suggested conducting several experiments in growing plants from seed, including growing plants in the closet to determine their need for sunlight. Jennifer also on occasion provided students with short articles related to plants which they discussed in their groups, and a parent came in and talked about growing tomato plants in his garden.

At the end of September, on the basis of the information they had gathered and their new focus areas, students renamed their five topic groups to: **(1) water; (2) roots; (3) dirt/nutrients/fertilizer; (4) animals/bugs and (5) sunlight**. They then spent several days developing visuals to illustrate the information their group had gathered to share that information with other groups. Once this jigsaw procedure had occurred, students formed **new (presentation) groups** based on the students they were normally seated with in the class. Jennifer instructed students that they were to provide Dr. Thompson with advice about her plants in some form as well as develop a visual to accompany their presentation.

In mid-October, the five presentation groups presented their overall **solutions**, based on information from all the topic groups, to the class (again videotaped for Dr. Thompson). Jennifer developed a rubric (described below) for assessing the presentations. Group 1 had videotaped a "newscast" at one student's house in which a "newscaster" interviewed the other group members portraying representatives of a garden company. They also wrote a letter to Dr. Thompson, which they read aloud, primarily advising her to water her plants more and to use plant fertilizer. Group 2 had developed a booklet with illustrations for Dr. Thompson in which they presented their advice and information about roots, soil, fertilizer and cost, watering, sunlight, and deterring animals. Members of the group gave some information about where they had located their information. Group 3 presented a live newscast consisting of an interview with "Dr. Thompson", as portrayed by a student. In their letter to Dr. Thompson, this group presented one of the most specific solutions to the problem of her plants losing their leaves, namely: not watering enough and animals eating the leaves. They gave recommendations for watering, light, fertilizer, and dealing with the animals. Group 4 had audiotaped a "radio talk show" with "callers" asking questions to a student portraying a scientist. In the group's letter to Dr. Thompson, members described necessary sunlight and explained photosynthesis, gave directions for planting seeds, and discussed the animal problem, also giving costs for putting up a fence and for fertilizer. Group 5 presented a videotaped skit acting out the process of growing a healthy plant. In their letter group members suggested that Dr. Thompson was not watering her plants enough and had planted them where they got too much sun.

After each presentation, Jennifer asked questions of the group members, both to probe their understandings more deeply and to clarify what they had said. She also built into the rubric for the presentations feedback from the class about positive and negative points in the presentation.

PLANT PROBLEM RUBRIC

WORK AS GROUP	___ / 2
VISUAL	___ / 2
WRITTEN ADVICE	___ / 2
SOLUTION	___ / 2
TOTAL POINTS:	___ / 8
CLASS FEEDBACK • 2 good points • 2 things to work on	

In summary, in addition to using the final presentation as an assessment, Jennifer also incorporated an ongoing *integrated log* in which students documented their updates of the problem frame, wrote information gathered, and asked questions and proposed solutions about the problem. She integrated her spelling, reading, writing, and math work during the PBL experience to also center around plants. Jennifer's students worked specifically on this problem for about 45 minutes a day, four or five days a week, for four weeks. In this problem, Jennifer incorporated the following science curriculum outcomes:

- use of the scientific method
- ecosystems
- growing healthy plants
- parts of plants
- photosynthesis

Jennifer, in an interview immediately following the problem, commented:

> I did not see a right answer or a wrong answer. I saw the kids learn that this problem taught them a lot about plants and, if anything, they now know a ton of information about plants, and they know that if they're going to have a garden they need to really read directions and they need to maybe know some conditions of sunlight . . . I didn't have to do it from a textbook. They learned about the ecosystem. They learned about food chains. They're much more enlightened now then they were four weeks ago.

Student comments following the problem included:

- I liked working on the problem because we got to use everything we wanted; we could use the computer.
- A good thing about it was that you could do a presentation any way your group wanted to.
- I wish we could have gone to Dr. Thompson's house to look at her garden up close.
- I think people should have practiced their words for their presentations.

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- I learned that roots can grow together but they don't snap, and I learned how much water plants need.

PBL in Nancy and Miranda's 8th Grade Classes at Ellsworth Middle School: The Prairie Problem

Nancy, an experienced language arts teacher, and Miranda, a younger science teacher with previous work experience in a laboratory, are in their second year of combining their 4th and 5th period classes into a PBL section and teaching the content in their classes almost exclusively through PBL. They teach in a different suburban district than do Carol and Jennifer. Nancy and Miranda are on the same 8th grade team in their middle school and decided several years ago to work on developing this PBL class after attending training through the Center for Problem-Based Learning. They decided to go to an "all-PBL" format because of their beliefs about teaching and learning and because they felt running only one problem in the course of a year didn't allow students to make enough progress in their thinking skills and problem-solving ability to maximize the effects of PBL. They were able to schedule this class by placing students in 4th period science and 5th period language arts (or vice versa) and using these two periods either to remain separate for work or to meet together for parts or the whole two-period time block (100 minutes) during certain parts of the PBL experience. They were also able, when necessary for field trips, to use the advisory and lunch periods that followed their class periods, creating a total possible time block of about two and a half hours. There were approximately 55 students in the combined classes, creating crowded conditions when all students met together in Nancy's room.

Last year students were randomly assigned to the PBL section, but this year more deliberate choices were made, with assistance from guidance counselors, in some cases. Several students have transferred out of the PBL section this year, due either to strong parent preference or to behavior issues. Last year the teachers designed and implemented four problems, each lasting the better part of a quarter, to teach their science and language arts curricula. This year the teachers designed two new problems, the prairie problem described here, a sound and light problem, and are using two of last year's problems--a genetics problem about predisposition to violence and a transportation system design problem--as their curriculum. The teachers, during problems, occasionally take a day or so each week to focus on something else, like reading days or writing days in language arts or labs in science, although typically these activities are integrated with the problem content as well. Nancy and Miranda did the bulk of the work of designing the prairie problem, centered around areas planted as prairie on their school campus which were not being maintained properly, at an advanced PBL institute last summer.

Nancy and Miranda's classes met separately for most of the first several weeks of school as they **prepared** their students for the PBL experiences they would have the rest of the year. They gave some information about PBL and why they chose to use it. They talked with students about the learning process and how the brain works. They also prepared students for more cognitively complex tasks through some thinking activities designed to encourage students to synthesize information and to be more fluent and flexible in their thinking. Many students coming into their classes have not had to be such active thinkers and struggle with this initially, as well as with the ambiguity of some activities. Finally, the two teachers decided to run a "mini-problem" this year (over two days) as a "role model of how you go about a problem". They placed students in the role of educational consultants who had to develop a 2-day curriculum for a training program for workers hired to clean up a site contaminated with thorium. During this mini-problem students clearly struggled with group process, synthesizing a vast amount of data, and coordinating their information with a good solution to the problem (developing an appropriate curriculum).

In mid-September, the 55 8th-graders **met their first problem** by receiving a copy of a (created) letter to an actual area conservation group from a concerned area citizen. She raised several issues about their school's campus area, specifically several areas planted as native Illinois prairie several years ago when the school was built that are now being mowed regularly and are bounded by creosote-treated railroad ties as well as adjacent to a wetlands area on the campus. (While all issues raised in the letter are real, the teachers "created" the person who was the stimulus for the problem.) The president of the conservation group, an acquaintance of Nancy's, spoke with the students and asked them to help her group research and solve this problem with the prairie on their campus.

Next, the students examined the letter closely for information while Nancy and Miranda coached them through the development of a **problem statement,** using the prompt "How can we . . . in such a way that . . . " to consider both the nature of the problem and the conditions under which it must be solved. Their problem statement was:

> **How can we learn more about the prairie around our school in such a way that it doesn't take a lot of time, it doesn't cost too much, and it helps the prairie?**

Nancy and Miranda identified the next step "problem-solvers do" as identifying what they **know** and what they **need to know**. Students, in scrutinizing the letter and recalling what the president of the conservation group had said, made suggestions, some of which are indicated below:

KNOW (samples)

- plants are getting mowed
- P.E. teachers ride over the prairie area with golf carts
- prairies contain unique plants
- most of Illinois used to be prairie
- fires can help a prairie grow
- creosote is an oil-based preservative that burns well

NEED TO KNOW (samples)

- what is currently happening to the prairie?
- are the railroad ties harming anything?
- what did the site look like before the school was built?
- are people getting instructions on how to care for the prairie?
- what is the muck on top of our pond?

Students also recorded the know and need to know statements in their *science logs*, which they would use to record all information about the problem and to respond to specific prompts. After about a 50-minute session, the teachers led students outside to examine the areas that had been planted as prairie, one of which is now overgrown with weeds, while another area that has been mowed appears to look like regular grass. A few students were engaged in asking questions and examining the areas closely, but many simply wandered around, glad to be outside on a nice day. I found it hard to tell in initial parts of this problem if students simply weren't interested or if they did not know how to investigate the problem. It seemed clear in talking with the teachers early in the problem that wanting to be ecologically correct was not a motivating factor to many students; however, what did seem to "hook" students into this problem was the fact that staff members at the school were clearly taking actions that were not preserving the prairie areas as had been intended.

The next day, the teachers placed students in small **information gathering** groups (determined by the teachers for "management reasons"). There were either 2 or 3 groups for each of the following categories: **(1) prairie plants; (2) wetland plants; (3) prairie animals, soil and water; (4) wetland animals, soil and water; and (5) man-made problems**. Students then did several days of research in the school media center or in the class using resources the teachers had collected. During the next week they took a field trip to a local restored prairie area where volunteers led small groups of students on tours to identify plants, collect seeds, and answer questions about the maintenance of the prairie. After the field trip, the teachers decided to **revisit the know/need to know** boards to update them with all the new information received. The teachers also invited two speakers into the class; one the building's head custodian who presented his perspective that the prairie should be mowed to be more attractive and to keep the mosquito population down, and the other a local specialist on maintaining prairies. The students also attended an all-day team building activity (a ropes course) and conducted more research in their small groups.

The third week started out with a great deal of confusion and frustration among at least the small group of students I was interviewing. They had concerns with the ambiguity of the problem and didn't seem motivated to work hard to solve it. As I discussed this with the teachers, they shared their insights from the previous year about how much students struggle in the first PBL experience in their teams, with their thinking, and with uncertainty. They felt this student frustration was an inevitable part of the PBL process as students struggled with new ways of learning. As Nancy continued to assign students to read regularly and to write on some specific prompts, Miranda had students do a lab on osmosis (later coaching students toward seeing the relationship with the creosote leaking into the wetlands area) and did a jigsaw activity in which the various small groups shared information with each other. Some days the large group met together briefly, but mostly worked as two classes or as small groups.

Late in September the teachers invited the original landscape architect of the school site to speak with the class and answer questions. He provided students with copies of the blueprints for the original site plantings and informed students that an escrow account had been established for maintainence of the prairie. This unexpected piece of information led some students on a quest to try to get information from the district treasurer about how this fund was being used. The teachers also used a "memo" from the president of the conservation group in which students were asked to update her on their progress so far as a midpoint assessment in the problem. I was observing some not surprising but significant group dynamics, including how different students were leaders in their small groups than the ones who were leaders in whole class discussion; that girls tended not to speak up in whole class discussions; that different students were motivated by different aspects of the problem; and particularly that some students were more motivated now that they realized they could impact on a real problem in their school and district and especially might be able to unearth somewhat of a controversy over the lack of prairie maintenance. The teachers **revisited the problem statement**, which now became: *What can we do to the prairie that will be in the best interest of the school and the students in such a way that it doesn't cost us a lot, won't have to bew redone, and won't take forever?*

In early to mid-October, students continued to research the problem. Students listened to a phone interview with another individual (now out of state) who had been involved in planning the original site and had some cost information about the original plantings. Miranda implemented several more science labs on plant structure and on photosynthesis. Nancy asked students to write a persuasive letter to the school board outlining what they thought should be done with the prairie areas. The teachers again formed new **solution groups** comprised of individuals representing each of the previous research groups. The solution groups met together for a little over a week before the planned presentation of their solutions to a panel of experts. The teachers gave specific **requirements for the presentations**, including: equal role from all group members; stating your problem statement; stating your solution clearly with timeline, budget, materials, etc.; and justifying your solution.

The teachers invited a number of "experts" to be present as a panel to whom students would present, including school district personnel, conservation group members, Board of Education members, and people involved in the original planning of the site. Two separate days were established for presentations (with two different panels) since there were a large number of small groups who needed to present their solutions.

Over the two days of presentations, there was a great deal of variability in how well prepared groups were with information, in their presentation skills, and in their ability to handle questions from the panel. Overall, students suggested education for those involved in maintenance and involvement from the local conservation group through money still in the escrow account, as originally suggested. Most groups outlined the need to replant the areas and then to maintain them by keeping people from walking/riding over them and by reseeding and doing controlled burns periodically. The experts on the panel were mostly impressed with the work students had done; however, they pointed out through their questioning a lack of clarity on costs and on the human resources necessary to restore and then maintain the prairie areas. One Board member who had been on a similar panel at the end of last year commented on the difference in student skills from last year, the end of a year of PBL experiences to this, the beginning of PBL experiences. The two experiences seemed made a powerful personal impression on her regarding the power of PBL to increase students' ability to problem solve and to present solutions accurately and completely.

The teachers **debriefed** students after the presentations and then began a 2-week period of work on **final projects** related to the problem. Students had chosen to be on a committee developing one of three products for the school: (1) a movie; (2) a model of the prairie; and (3) a mural of the prairie. When completed, these products were presented to the principal. As a final wrap-up, students evaluated the other members in their group for contributions as well as the overall functioning of their groups.

In summary, Nancy and Miranda led their 8th-grade classes through the process of solving a complex and authentic problem at their school centered around prairie sites that had been planted but not properly maintained. Their classes worked on this problem for one or two class periods a day, four to five days a week, for five weeks, and then spent two additional weeks developing final projects for the school. After the students presented their solutions, school board members and district personnel traded several memos to determine what to do about the prairie maintenance, but, as I write, I am not aware of major new action that has been taken by the district with regard to this issue.

Nancy and Miranda incorporated a number of science and language arts curriculum outcomes in this problem. A few samples include:

- ecosystems (prairie and wetlands) and the connections among ecosystems
- plant structure
- ecological and environmental issues
- plant growth/photosynthesis
- osmosis
- political awareness
- writing persuasive letters
- reading and synthesizing data
- reading for information
- editing
- public speaking/interviewing

The teachers included a number of formative and summative assessments in the PBL experience as well, including:

- ongoing student science logs
- student webs (two different times) that reflected their current understanding of the problem
- persuasive letters to the school board
- mid-problem assessment - giving president of conservation group an update on progress
- presentation to panel of experts
- content assessment by writing as many facts as you know about the prairie/wetlands at the end of the problem

- group project (movie, model, or mural)
- individual language arts assignments such as reading logs
- individual science assignments such as labs

Students, at the end of this first PBL experience, said things like:

- We should have been more prepared for the questions they asked and maybe put that stuff in our report.
- I think we need more time to prepare . . . to put our information together and have a report ready.
- I like this more than a regular English class . . . more than just going in and reading stories and doing grammar.
- I think we should get a chance to pick the problem we do.
- It got more interesting. We just started working with a solution and it was less boring than just sitting in a classroom listening to a speaker.
- Everyone else listened to the presentation and you could tell from the people who really cared cause they called back and gave us the information we asked for.

In interviews from last year, the teachers remarked:

> Nancy: A positive thing is when you do go - so to speak - go public, and we've had some panels of experts come in and hear solutions from our groups. The adults are just astounded by the depth of their knowledge, the breadth of their knowledge, the kinds of things they've been able to deal with, and, you know, we've gotten nothing but very positive feedback. Even experts who've come in as resources, thinking they're going to give kind of a canned speech on the wetlands, and, you know, the kids just cut to the quick, and: Well, I think I'll leave 5 minutes for questions, and I said, Well, you know, excuse me, but could you present for 5 minutes and then we'll have an hour of questions.
>
> Miranda: I think one of the things PBL also does is it helps you redefine what you feel is important in education. From a science perspective, I think that, well, speaking for a science teacher, I think that people become very protective of their content area, you know? For a long time I think we sat in our rooms and said, Kids MUST know this. They MUST be able to recite the nine phyla of the animal kingdom. And I think that doing PBL, it helps you to re-evaluate what is important and what is not important. It helps you give some perspective, and it makes you question -- I think it constantly makes you question, Is this important for kids to know? What will make them better students? What will make them better learners; what will help them more in life?

Preliminary Conclusions/Implications

In the process of collecting this data and of beginning to think about analyzing connections and ideas based on the data, I have begun to categorize my own thinking about problem-based learning with elementary and middle school students into three areas: (1) the **design** of problems; (2) the **implementation** of PBL in real, diverse classrooms; and (3) the nature of PBL itself as a **curriculum and instructional strategy** -- if you will, its strengths and weaknesses. I have also been enlightened to focus on *maximizing the effects of PBL* by Bridges and Hallinger (1991), who stress a research focus not on comparing PBL to other strategies, but rather focusing on how effective various models of PBL are in achieving the outcomes you desire. Some of my thoughts in these areas follow.

Design

There are a number of issues surrounding the design of ill-structured problem experiences for elementary and middle school students. If indeed the use of ill-structured problem scenarios (PBL) is effective with young students, one practical question becomes, Where can a teacher find or develop such problem scenarios? Several organizations are developing problem scenarios and/or simulations in various disciplinary areas, but these problem scenarios are often structured so that students are led toward one conclusion or are limited in exploring the full range of the problem. Additionally, for PBL problem scenarios to have "worth" for particular teachers and schools, they must align with curriculum outcomes of worth. Using pre-packaged problems may force a fit to the outcomes that problem was developed for.

However, even with these "givens," if teachers/schools want to develop their own problems, how can they realistically do so? Northfield Elementary's district developed a design team that meets regularly to design problem scenarios that are then disseminated to various teachers in the district. While this model eliminates the need for each teacher to design problems on her own, it also does not allow for teachers to incorporate individual outcomes of worth, unless they are experienced enough in problem design to adapt the problem themselves. The teachers at Ellsworth design all their own problems, which allows them more control over content and skill outcomes incorporated but also becomes very time-consuming and resource-intensive. Using particular problems as models for various content outcomes and/or for various types of learners and encouraging reflective individual adaptation may be the best strategy.

Other design issues include student role, motivation, developmental level, and problem authenticity. Often K-12 teachers place students in a role outside themselves in a problem (for example, in the mini-problem at Ellsworth, the 8th graders acted as educational consultants). This is a unique aspect of K-12 PBL; to explore complex, real-world issues, students may learn more by being assigned to a role of more authority than they as young students would have. Certain roles and certain particular issues also seem more inherently motivating to students at various ages. Should teachers allow students to select the content of problems they work on? Does the use of props (for example, letters on authentic letterhead), drama (for example, introducing the problem with a staged incident), or a particular role (for example, how would the prairie problem have changed if students were in the role of landscape architects?) maximize learning in PBL, and if so, how? More research focused on these questions would help us make more informed design decisions.

Finally, issues of authenticity often arise. Many times actual community or school problems may be used in PBL (for example, the prairie problem). Does incorporating created aspects (such as their meet-the-problem letter) help engage students more in an already real problem? At Northfield, issues around the authenticity of another problem later in the school year became problematic as some community members thought the new principal was actually censoring fantasy and fairy tale books in the library, rather than questioning the worth of these books as the stimulus for a problem. How can we engage young students in real problems with real worth without creating situations in which we are potentially misleading students about their power and authority to impact on a solution? What about parents who don't support their children's exploration of messy, real-life issues in open-ended ways? What about potentially controversial problem topics? Teachers and schools designing PBL experiences may need to consider these and other issues.

Implementation

The implementation of PBL in K-12 classrooms looks very different from PBL in medical education. Typically medical students meet in tutorial groups of 5 or 6 students, with a facilitator present for each group, for 2 or 3 hour blocks of time. In a typical classroom, teachers facilitate four or five such groups simultaneously with learners who have very different characteristics and prerequisite skills from those of graduate students. For example, Carol could not expect most of her 1st graders, at the beginning of the school year, to go off and find and read resources independently in-between class sessions. Additionally, most teachers cannot manipulate their schedules enough to provide long blocks of time for PBL on a regular basis, although Nancy and Miranda deliberately planned for this option with their two back-to-back periods and the option of using advisory and lunch periods as well. How can we maximize the effects of PBL in a typical classroom in which there are large numbers of students and limited amounts of time?

Certainly the skills of the teacher as a coach and facilitator of learning as well as of classroom management come into play here. At the Center for Problem-Based Learning, we suggest that teachers of PBL adopt a strategy of model/coach/fade throughout PBL experiences. For example, to facilitate effective small group functioning, teachers may need to model a skill like active listening, then coach group members in active listening, and finally "fade" to allow the groups to facilitate active listening among their members on their own. The teachers in this study chose a number of strategies for small group work: Carol selected the topics for inquiry but allowed students to self-select groups and then continued with topic groups throughout the problem; Jennifer had students select both their groups and their topics and then re-structured presentation groups near the end; Nancy and Miranda selected both the topics and the students in research groups as well as in the reformulated presentation groups. Clearly developmental level of students plays a part in what role teachers of PBL take, and what decisions they make, in their classrooms. As these teachers and I have discovered, it also requires some deep reflection about personal conceptions of teaching and learning, the role of the teacher and the students, and the outcomes of the educative process, and consideration of the fit of our beliefs with what is required of us in PBL (Richardson, 1990).

Teachers' knowledge of their subjects and their ability to encourage student inquiry are also key in PBL. Carol and Irene, immediately after framing the plant problem, spoke about how much learning more about questioning strategies and deliberately questioning students toward deeper levels of thinking and understanding helped make the initial session to meet the problem more engaging and brought out more of the students' knowledge. Brooks and Brooks (1993) suggest that constructivist teachers ask thoughtful, open-ended questions; seek elaboration of students' initial responses; and engage students in encountering contradictions to their conceptions. Many teachers are unaccustomed to and unprepared for such a role in their classrooms. One strategy we have found particularly helpful in professional development for PBL is to use PBL itself to train teachers; in other words, to provide opportunities for them to experience PBL as learners and to model appropriate coaching strategies.

Finally, there is great variation among resources available to teachers and students. In both these schools students had access to telephones in their own classrooms. However, while students at Northfield had regular access to Internet resources, students at Ellsworth did not. How can we maximize appropriate use of resources by students in investigating problems? How does their developmental level and skill level impact resource use? For example, if primary students have mostly print resources available to them, how can those resources be most useful? Or is it more useful for them to have access to online resources with lots of pictures, or for them to take the lead in contacting people in the area who are resources? Several students in Carol and Jennifer's class were "hung up on" in their information gathering phase by individuals who thought they were just kids playing a prank, even though the young students were using very appropriate telephone skills. It is clear that library/media specialists in elementary and middle school buildings play a large role in helping students access appropriate resources, and often become integral parts of the PBL experience.

<u>PBL as a Curriculum and Instructional Strategy</u>

The real difference between PBL and other active, experiential forms of learning is that PBL places students squarely in the middle of a messy, authentic problem that changes as you go along and has no one right answer. In PBL, students learn content in the context of such "ill-structured" problems. Is this an effective way for students to learn and retain content? Shahabudin (1987) suggests this makes the content more relevant to students; Needham and Begg (1991) find that the transfer of concepts to new problems (certainly a desirable outcome in to most educators) is higher when concepts are learned in the course of such problem solving. We know that "wisdom can't be told" (Bransford et al., 1989) but comes from the opportunity to experience change through such ill-structured problems

(Kitchener, 1983; Carter, 1988; Dunkle et al., 1995) However, the majority of research on specifically linking the use of ill-structured problems to student learning was conducted with adult learners. There is a critical need to examine this relationship more closely with young students.

The teachers at Northfield use a slightly different model of PBL than do the teachers at Ellsworth. How can we examine what model, or what parts of each model, maximize effects for student learning? **Perhaps the key here is identifying what our most critical outcomes for the PBL experience are.** Is "covering content" most critical? What about thinking skills and problem solving? What about service to the community? What about interpersonal skills and functioning effectively in a group? Frederiksen (1984) raises several questions about teaching problem solving, including: *Should instructional methods vary with the specific skills of the learner?* and *How general should instruction in problem solving be?* Gallagher, Stepien and Rosenthal (1992) have documented significant growth in *problem finding* , a critical component of problem solving, among gifted high school students in a problem-based learning class. Does PBL have this effect on other K-12 learners?

Another interesting component of PBL in these schools and others is its level of acceptance by students, other teachers and administrators, and community members. While the teachers in this study might be considered trailblazers or pioneers (Schlechty, 1993), others in their schools were "stay-at-homes" who didn't choose to be involved in implementing PBL or even "saboteurs" who were opposed to the changes implementing PBL requires. The larger community must certainly be educated about PBL and even, in some cases, shown proof through student work, student and teacher presentations, and research studies that PBL is indeed "doing no harm" to students, particularly in basic content acquisition, and is adding some value to students. Like any major educational innovation, PBL must be implemented with knowledge, reflection, and especially ongoing support.

Perhaps further analysis from this study, as well as other ongoing research in PBL with K-12 students, will give us important information to begin answering some of these and other critical questions. Toward that end, I welcome dialogue with persons interested in and/or conducting PBL research with a variety of learners and especially with K-12 students.

References

American Association for the Advancement of Science, Project 2061. (1993). Benchmarks for science literacy. New York: Oxford University Press.

Barrows, H. S. & Myers, A.C. (1993). Problem-based learning in secondary schools (Monograph #1). Available from the Problem-Based Learning Institute, Springfield, IL.

Barrows, H.S. & Tamblyn, R.M. (1980). Problem-based learning: An approach to medical education. New York: Springer.

Bransford, J.D., Franks, J.J., Vye, N.J. & Sherwood, R.D. (1989). New approaches to instruction: Because wisdom can't be told. In S. Vosniadou and A. Ortony (Eds.), Similarity and analogical reasoning (pp. 470-497). New York: Cambridge University Press.

Bridges, E. & Hallinger, P. (1991). Problem-based learning in medical and managerial education. Paper presented at the Cognition and School Leadership Conference, Nashville, TN.

Brooks, J.G. & Brooks, M.G. (1993). The case for constructivist classrooms. Alexandria, VA: ASCD.

Carter, M. (1988). Problem solving reconsidered: A pluralistic theory of problems. College English, 50, 551-65.

Center for Problem-Based Learning. (1995a). Center for Problem-Based Learning brochure. Aurora, IL: Illinois Mathematics and Science Academy.

Center for Problem-Based Learning. (1995b). Introductory documents. Aurora, IL: Illinois Mathematics and Science Academy.

Dunkle, M.E., Schraw, G. & Bendixen, L.D. (1995, April). Cognitive processes in well-defined and ill-defined problems. Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Gallagher, S.A., Stepien, W.J. & Rosenthal, H. (1992). The effects of problem-based learning on problem-solving. Gifted Child Quarterly, 36(4), 195-200.

Gallagher, S.A., Stepien, W.J., Sher, B.T. & Workman, D. (1995). Implementing problem-based learning in science classrooms. School Science and Mathematics, 95(3), 136-146.

Kitchener, K. (1983). Cognition, metacognition, and epistemic cognition: A three level model of cognitive processing. Human Development, 26(4), 222-232.

Lincoln, Y.S. & Guba, E.G. (1985). Naturalistic inquiry. Newbury Park, CA: Sage.

National Research Council. (1996). National science education standards. Washington, DC: National Academy Press.

Richardson, V. (1990). Significant and worthwhile change in teaching practice. Educational Researcher, 19(7), 10-18.

Savoie, J. M. & Hughes, A. S. (1994). Problem-based learning as classroom solution. Educational Leadership, 52(3), 54-57.

Schlechty, P.C. (1993). On the frontier of school reform with trailblazers, pioneers, and settlers. Journal of Staff Development, 14(4), 46-51.

Stepien, W. & Gallagher, S. (1993). Problem-based learning: As authentic as it gets. Educational Leadership, 50(7), 25-28.

Stepien, W., Gallagher, S. & Workman, D. (1993). Problem-based learning for traditional and interdisciplinary classrooms. Journal for the Education of the Gifted, 16(4), 338-357.

Strauss, A. & Corbin, J. (1990). Basics of qualitative research: Grounded theory procedures and techniques. Newbury Park, CA: Sage.

U.S. Department of Labor. (1991). What work requires of schools: A SCANS report for America 2000. Washington, DC: U.S. Government Printing Office.

West, S. A. (1992). Problem-based learning - a viable addition for secondary school science. School Science Review, 73(265), 47-55.

Instructional Template for a PBL Unit

EMBEDED INSTRUCTION & ASSESSMENT	CRITICAL PBL TEACHING & LEARNING EVENTS
E M B E D I N S T R U C T I O N & A S S E S S M E N T	*Teacher as Coach* • *Prepare the Students* • *Meet the Problem* • *Know/Need to Know Boards* • *Problem Definition* • *Information Gathering & Sharing* • *Generate Possible Solutions* • *Fit of Solutions* • *Performance Assessment* • *Debriefing the Problem* ITERATIVE
Problem Coaching	

Appendix B

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