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Effectiveness of Problem-Based Learning in Middle School Science

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Abstract
Middle school science students appear to lack motivation when learning under teaching methods which reduce the subject of science to a body of facts. This study attempted to examine the effectiveness of problem-based learning as an alternative teaching method in sixth grade science. The participants were generally homogeneous representing mostly Caucasian children, and the classrooms were typical classrooms containing the normal range of abilities. Three variables were tested in a quasi-experimental pre-test/post-test control group design: attitude toward science, problem-solving ability, and knowledge. Results showed no significant effect for any of the variable as a result of the intervention. However, certain factors in the methodology of the intervention may have played a large role in affecting the outcomes.

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by

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The Effectiveness of Problem-Based Learning in Middle School Science

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Abstract

Middle school science students appear to lack motivation when learning under teaching methods which reduce the subject of science to a body of facts. This study attempted to examine the effectiveness of problem-based learning as an alternative teaching method in sixth grade science. The participants were generally homogeneous representing mostly Caucasian children, and the classrooms were typical classrooms containing the normal range of abilities. Three variables were tested in a quasi-experimental pre-test/post-test control group design: attitude toward science, problem-solving ability, and knowledge. Results showed no significant effect for any of the variables as a result of the intervention. However, certain factors in the methodology of the intervention may have played a large role in affecting the outcomes.
The Effectiveness of Problem-Based Learning in Middle School Science

The concept of science implies an orderly system of facts and definitions. However, there is more to science than just information. Science is also a way of doing something. It sets forth an orderly process for asking questions and seeking answers. If a problem occurs somewhere, the methods of science can be used as a guide in the search for resolution.

Because science involves more than a set of data or terminology, science instruction in the Christian school should entail more than imparting information. It must engage students in service. When taught from a Christian perspective, the subject of science challenges students to discover the treasures of creation and to use its components for the purposes God intended. It calls them to work for restoration where sin has caused decay.

Although many Christian school curriculum guides declare beliefs which are similar to these, the subject science is often delivered to students in a way that is inconsistent with this philosophy. For example, Stronks and Blomberg (1993) note that Christian educators frequently start with subject material that is detached from real-life contexts. "We think our task as teachers is to determine the logical structure of knowledge and then to transmit this to our students, rather than to take their hands and lead them as together we explore the creation" (p. 202). As a result, the students come away from school with a view of creation that is limited to facts and assertions, something that can be mastered. They miss out on the richness of the world's complexities and the excitement of discovery. And they rarely get a chance to struggle with issues and dilemmas that are so much a part of science in the real world.

Textbook-driven methods of instruction are likely to result in this type of limited experience for the learner. For if one's teaching implies that the textbook is the final authority, the students inherit the false view that science is a body of information to be mastered. Luke, de Castell, and Luke (1989) state that textbooks are not structured to
facilitate problem posing and critical thinking. Rather they are geared more for conveying information (cited in Stronks and Blomberg, 1993). This is not to suggest that textbooks are useless in the Christian classroom, for certainly the information contained in them is useful in the broader context. However, a textbook-driven science program seems to counteract a belief which holds that science must engage students in discovery and service.

Problem-based learning (PBL) is a teaching method that provides an alternative to textbook based instruction. With this strategy a real-world problem is the starting point for the learning unit. And the science book becomes a resource which contains much, but not all, of the information needed to solve the problem. Such a process does not devalue the textbook, but rather increases its value in the eyes of students. When children are confronted with a problem at the outset they have a reason for learning. They go back to the text as well as to other places to work out solutions. And as they hypothesize, research, and experiment, they experience science as a tool rather than as content to be mastered.

Some researchers have suggested that PBL is an effective alternative to the traditional method for teaching science (e.g., Checkley, 1997; Gallagher & Stepien, 1996; Gallagher, Stepien, & Rosenthal, 1992; Gallagher, Sher, Stepien, & Workman, 1995; Savery & Duffy, 1995; Stepien & Gallagher, 1993; Stepien, Gallagher, & Workman, 1993; West, 1992). Many report that student attitudes toward science are more positive, and that learners improve in problem-solving skills. However, critics argue that with nontraditional approaches like PBL students don't learn as much information (Gallagher et al., 1996; Stepien et al. 1993). They argue that PBL dwells too heavily on problem-solving skills, resulting in lower content acquisition.

The endeavor of this study was to determine whether or not problem-based learning could be effective in middle school science education. It posed three questions:

1. As a result of PBL, would students' attitudes toward the subject of science change
significantly?

2. Would students' problem-solving ability change significantly because of PBL?

3. Would there be a significant difference in content acquisition between students learning under PBL and students learning under the traditional method?

Definitions

In this study PBL is defined as a teaching method which uses an ill-structured problem as the starting point and reason for learning. An ill-structured problem has four characteristics: First, solving the problem requires more information than is originally available. Second, the definition of the problem may change as new information is found. Third, different perspectives are used for interpreting information. And finally, there is no absolutely "right" answer to the problem (Barrows, 1990, cited in Gallagher et al., 1992).

The model for planning is largely student-centered. Assuming the role of "facilitator," the teacher may choose the problem being studied and help the students to reflect on their thinking, but the activities for the class period are frequently determined by the questions students have generated about the problem (Savery & Duffy, 1995). The class structure is generally collaborative, although whole-class sessions are needed from time to time to share information and to strategize.

For the purposes of this study the traditional method for teaching science is defined as a teaching method which uses the goals and the activities of the textbook as the starting point for learning. The model for planning is more teacher-centered. The material is either assigned as homework or read and discussed in class. Hands-on activities may be used, but all of them fit within the stated objectives and enhance or deepen the understanding of the text. And though application types of problems may be assigned to the students, these exercises are given after the material needed to solve them has been presented. The teacher plans the steps of the unit and does most of the instructing, although students may also present findings to each other. And though
various forms of group work may occur, whole class sessions mark the typical instructional lesson.

Attitudes are feelings toward the subject of science as measured by an attitude scale. The scale was originally created by Germann (1988) and was modified by myself. Problem-solving ability is the competence which students display in solving ill-structured problems. This was evaluated by the number of problem-solving steps the students used in devising a strategy for solving an ill-structured problem: fact-finding, problem-finding, brainstorming, solution-finding, implementation, and evaluation (Gallagher et al., 1992). Content acquisition is defined as the amount of information pertaining to the unit that students are able to recall at the end of the unit. It was measured by a general concepts test related to the topic being studied.

I believe that science is more than a collection of facts and definitions. It is a tool: a process whereby the treasures of the universe may be discovered, and restoration realized in a world where sin has wrought decay and decadence. The subject of science, then, should engage students in the activities of discovering and restoring, rather than settling for a type of knowledge which consists only of facts and definitions. PBL offers some promising avenues. However, some reason that it could result in lower content knowledge. The purpose of this study is to determine the effectiveness of PBL in middle school science.

A Review of the Relevant Literature

I was drawn to this topic because of the lack of interest I had perceived among my students toward science as a subject. My methods up to this point had been largely textbook-based. Even though hands-on activities were a regular part my learning units, I had been disappointed in the students' apparent lack of motivation to learn the concepts taught in science class.

The literature seems to support the view that textbook-based instruction is not overly enticing to most students. Victor (1989) writes about rewards for learning. He
says that learning will be more efficient when rewards for learning shift from external rewards, such as pleasing the teachers and parents, to internal rewards, such as interest and accomplishment. A science program that follows the text de-emphasizes learning for internal rewards. It would appear difficult for the teacher to take the child's interests into account in the planning process when the text has already determined the content and the activities which support it.

The American Association for the Advancement of Science (1990) notes that students often find science dull and difficult to learn. Science is seen by students as an academic activity rather than as a way of understanding their world. The Association calls teachers to choose activities which are "significant, accessible, and exciting" and focus on "exploring and understanding rather than rote memorization of terms" (p. 187). While it is true that a textbook-based method of teaching could employ exciting activities which focus on discovery, the inquiry done by students is still determined by the text and not usually by their own desire to learn.

Furthermore, the fact that many science textbooks include a "motivate" or "motivation" step at the beginning of every lesson almost implies that the lessons in textbooks are not motivating in themselves, that students must somehow be lured into focusing on the topic being presented rather than participate out of their natural desire to learn. While nontraditional methods also must be presented in a way that is motivating to students, the level of eagerness seems to be more difficult to sustain under textbook-driven methods.

Several researchers claim that the problem goes beyond attitudes. Gallagher et al. (1995) state that science education in the precollege classroom is not producing scientific literacy. Students do not understand basic science concepts, the process of science, nor how science impacts society.

Smith and Good stress the need to teach problem-solving skills rather than transmit material (1984, cited in West, 1992). The information explosion has proved that
no student can learn all of the information that is needed in order to be effective in society. And even if this could be accomplished, the information would quickly become outdated. What is needed is for students to possess the skills necessary to understand information and to be able to apply it to new situations.

While it is true that students are often asked to solve problems in school, Barrows observes that the problems children solve in school aren't like the problems they encounter in the real world:

Only in school can students expect to be given all the information they need to solve a particular problem; only in school can students use a formula to arrive at a single solution to that problem; and only in school can students be absolutely certain that the solution they propose is the right one... (Barrows, date unknown, cited in Checkley, 1997).

PBL utilizes problems which go beyond neatly defined questions and answers. Since the ill-structured problems of PBL contain insufficient information and often have more than one "right answer," they tend to look more like the problems people encounter outside of school.

The technique of PBL has been around since at least the 1970s in various medical schools. It was first used by Barrows and others who found that medical students were graduating with lots of head knowledge but were lacking the skills necessary to use it wisely (Gallagher et al., 1995).

Not until recently has PBL been tried in precollege education. Many schools are now picking up on the concept in one form or another. Although it is used in interdisciplinary classrooms (Checkley, 1997), PBL seems to show up most often in science and social studies oriented classes (e.g., Gallagher et al., 1995; Gallagher & Stepien, 1996; Stepien et al., 1993; West, 1992).

Those who have tried PBL report that it motivates students (Barrows in Checkley, 1997). Its very nature fuels the natural flame of curiosity in children because they
actually become the scientists, taking responsibility for the problem and feeling ownership in the learning process (Gallagher et al., 1995).

The technique has been proven in at least one case to enhance problem-solving ability. In a semester-long study with high school students, the participants became better problem solvers because of PBL (Gallagher et al., 1992).

Gallagher and Stepien (1996) report that critics argue against PBL because it overemphasizes problem-solving skills at the expense of content acquisition. Even some of the proponents warn about the dangers of ignoring content as well as the inefficiency of having students learn this way (Barrows & Tamblyn, 1980, cited in West, 1992).

Not everyone feels the same, though, about content acquisition in PBL versus traditional learning. In one study comparing traditional learning with PBL in an American studies class, "the students in the problem-based course gained as much, if not more, factual content" than the students in the more traditional classrooms (Gallagher, Stepien, & Stepien, in preparation, cited in Stepien, et al., 1993). In a similar study Gallagher and Stepien found that PBL did not result in lower levels of fact acquisition (1996). As a matter of fact, the students enrolled in the PBL course experienced the highest gain of any of the groups being tested. Furthermore, students retain information longer through the use of ill-structured problems than students who learn through teacher lectures (Boud & Feletti, 1991, cited in Gallagher et al., 1995).

A possible criticism in the Christian community might arise from the constructivistic views associated with PBL. It is true that the concept of PBL bears certain assumptions which are constructivistic. Savery and Duffy (1995), advocates of constructivism, assert that understanding happens through interaction with the environment. Meaning is constructed individually on the basis of one's own experiences. Students cannot share understandings since each person has had different experiences. Therefore students test the compatibility of their understandings through collaboration with others. PBL provides a stimulus for learning because the learners are faced with a
"puzzlement," and the nature of the method facilitates collaboration to test individual understanding.

There is little in these assertions, however, that Christian educators should be alarmed about. For most Christians would agree that children are made in the image of God, and that as such they are not empty-headed receptacles that teachers drop knowledge into. In the PBL approach, it is "essential that the teacher value as well as challenge the learner's thinking" (Savery & Duffy, 1995, p. 33). Teachers who use PBL assume the worth of the child in addition to the worth of the subject material. Most Christian schools also try to promote the concept of community by saying that all the members of the classroom ought to share with one another and support each other. The collaboration needed to carry out PBL is compatible with this idea as well.

Of course, any philosophy which is carried to the extreme can be cause for concern. Savery and Duffy (1995) reject the concept of ultimate truth. They state that "facts are facts because there is widespread agreement, not because there is some ultimate truth to the fact" (p. 32). The constructivists would also support pluralism (Lebow, 1993, cited in Savory & Duffy, 1995). Pluralism essentially assumes that different people can hold contradictory beliefs about a particular issue and still both be right. While it is true that ill-structured problems in PBL may have more than one "right" answer (Barrows, 1990, cited in Gallagher et al., 1992), certain beliefs must govern the decisions and actions of the classroom in the Christian school. For example, a Christian teacher would hopefully never agree that stealing or cheating would be an acceptable solution to a problem if that is what the learner had proposed.

The current literature on PBL seems to support its use in the Christian school if and when it is guided by biblical parameters. However, it appears that the testing of this technique has been quite limited. Though many advocates speak of positive motivation among students learning with PBL, I found no evidence of actual testing of students' attitudes toward science as a result of PBL. The research also seems to be limited, so far,
in terms of variety among age groups of participants. Gallagher and Stepien (1996) and Gallagher et al. (1992) focused their studies only on gifted high school students.

Gallagher and Stepien (1996) call for more research with different instructors, different students, and different approaches. Gallagher, Stepien, and Rosenthal (1992) state that more studies are needed which focus on problem-solving skills.

Stepien and Gallagher (date unknown, cited in Checkley, 1997) state that PBL should be tried in the earlier grades. They believe that the children are developmentally suited for the technique because they are the ones who generate the questions. Therefore, the learning topics are at their cognitive level of understanding.

This study attempted to extend the research that is currently available on PBL. It is unique with regard to the participants in two ways: (1) the students are pre-secondary, and (2) the students vary in academic ability since most studies have involved only groups of students defined as gifted. The attitude variable was dependent on the students' feelings toward science as a subject as a result of PBL. The inclusion of a problem-solving variable was meant to determine whether the PBL strategy affected the problem-solving abilities of students. The content variable examined whether problem-based learning affected content acquisition. All of these variables fit within the broader question of whether PBL could be effective as a teaching strategy in middle school science.

Methods

Participants

The study involved participants in an experimental group made up of two classes (n=55) and a comparison group also made up of two classes (n=43). All of the participants were sixth graders in two private Christian day schools located in small cities in the Midwest. The participants were generally homogeneous representing mostly Caucasian children, and the classrooms were typical classrooms containing the normal
range of abilities. All groups used the same textbook, *Science* (Christian Schools International, 1994).

**Materials**

On the first day of class the students in all groups were asked to complete the attitude scale (see appendix A). The original Attitude toward Science in School Assessment scale (ATSSA) by German (1988) was found to be valid and reliable by Germann (1988). The units were taught during the fall semester to both the experimental and comparison groups to avoid confounding the attitudes variable.

Experimental and comparison group students were also administered a problem-solving pre-test on the first day of the learning units. This pre-test as well as the post-test roughly parallel the model designed by Gallagher, Rosenthal, and Stepien (1992). An ill-structured problem was given to students along with directions for outlining steps which could be used in finding a solution to the problem (see appendix B). To establish reliability an independent co-rater and I first categorized the responses individually, and then came to a consensus on the categories.

Finally, the students took the general concepts pre-test on the information that would be covered in the learning unit (see appendix C). The general concepts test was written by myself and shown to all of the teachers of the classes participating in the study and to another teacher and a college professor not involved in the study. Their examination established that this was a valid test of the concepts taught in the student text.

**Intervention**

Both the experimental and comparison groups studied a unit on ecology. The intervention in the experimental group was the application of PBL in studying the ecology unit.

For the experimental group the unit was divided into three phases. In the first phase students examined an apparent problem with birds in the community. Every
autumn thousands of blackbirds roost in the town's trees, causing significant noise and
depositing large measures of dung. Many of the people in the community have attempted
various tactics to keep the birds away, but most of their attempts have resulted in only
short-term relief. The project required students to study the concepts of ecology as they
relate to this problem. The student textbook was to be one resource among several, such
as bird books, local bird experts, and articles or books from the library.

Part of this phase also involved a smaller problem-based project dealing with the
issues of prairie restoration in another part of the state. Students assumed the roles of
stakeholders in this case and debated whether or not the restoration project should take
place.

The second phase of the unit involved learning more of the information in the
text. Because the unit in the student book is broader than the issues related to the birds
and the prairie, several concepts not directly related to this problem would have been
missed if these ill-structured problems had been the only focus of the unit. Teaching this
material directly, however, would have confounded the knowledge variable, so the
students were divided into cooperative learning groups for the second and third phases of
the unit. Each group was given a section of the textbook to learn and teach to the others.
The ill-structured problem, then, was a metacognitive question. The students needed to
struggle with what would be the most effective way to present the material in their
section of the text.

The third phase of the unit needed to deal with the last section of the ecology
chapter which addresses "cultural factors." Cultural factors are anything that humans do
that affects ecosystems. Examples include deforestation, farm methods that cause
erosion, and oil pipelines that block migrating caribou. In this phase several cultural
factors were presented as ill-structured problems for the students to solve. The students
worked in cooperative groups to research the problems and to propose creative solutions.
Throughout the duration of this unit the teachers in the experimental groups assumed the role of "facilitator" (Savery & Duffy, 1995; West, 1992) or "metacognitive coach" (Gallagher et al., 1995). As such they helped the students to reflect on their thinking as well as keep the focus on the issues that relate to the their objectives for the unit. They determined the format of the class periods by leading the students in brainstorming sessions or by employing other methods which helped their students strategize. However, they did not structure a lesson around the content of the unit unless the students requested a presentation on a particular topic for the purpose of their investigation.

After the initial presentations of the problems the teachers facilitated the process of learning by use of the "Need-to-Know Board" (Gallagher et al., 1995) or by utilizing its concept in other forms. The thinking was categorized under three questions: What do we know, what do we need to know, and how do we find out? The teachers led the students through the six problem-solving steps outlined by Parnes (1966, cited in Gallagher et al., 1992). These can be stated as follows:

Fact-finding, the first step, involves searching for and compiling information. Then, in the problem-finding step, the class identifies the problem which is central to the issue. Next, the students generate a list of possible solutions to the problem by brainstorming. Solution-finding, the fourth step, involves evaluating the list that was brainstormed to consider which solutions are most workable. In the implementation step the students put the solution or solutions into place on either a permanent or experimental basis. Finally, the students evaluate the effectiveness of their solution.

Although the teachers in the intervention groups led their students through most of these problem-solving steps in each problem that was presented, they avoided confounding the post-test for the problem-solving variable by not mentioning the names of the steps except for brainstorming.
After the unit on ecology was taught the students filled out the ATSSA once again. They retook the problem-solving post-test, and they retook the general concepts of ecology test. Two students were unable to complete the final tests. Their scores were dropped from the study.

**Research Design**

The students for the experimental and comparison groups were not chosen randomly because the students had already been assigned to sections within their school systems. The design used in this study was a quasi-experimental pre-test/post-test control group design.

**Data Analysis**

Pre-tests and post-tests were given to experimental and control groups on all three variables: students' attitude toward science, problem-solving ability, and knowledge. T-tests were used to compare the pre-test scores on all three variables so that equivalency between the experimental and comparison groups could be assumed. T-tests were also used to compare the post-tests on all three variables to check for significant differences in attitude and problem-solving ability and to examine for any significant difference in the knowledge variable.

**Results**

The purpose of this study was to determine the effectiveness of problem-based learning in middle school science. Three variables were researched: student attitudes, problem-solving ability, and content acquisition.

Table 1 reveals no significant change in attitude for either the experimental or the comparison groups. Table 2 shows that the groups were not statistically equivalent in problem-solving ability at the beginning: the experimental group was actually farther ahead in this area than the comparison group. However, the problem-solving post-test scores show that the two groups ended statistically equivalent. This data is troubling because the comparison group had no formal training in problem-solving skills during the
experiment. Therefore, the validity of the problem-solving test is in question. According to Table 3, although the experimental group gained a small amount in their knowledge score, the comparison group appeared to have learned significantly more content.

Discussion

Because there was no significant growth in any of the three variables used in this study, PBL does not appear to be effective in teaching middle school science. If anything, the approach seems to be detrimental.

However, several factors played a significant role in weakening the success of the learning unit in the experimental group. Some of these factors were out of the control of the teachers involved. For example, the intense heat of the early autumn produced difficult working conditions, and the large class sizes compounded this problem. Inductive class discussion is an integral component of PBL. However, with the noise of five to six electric fans turning in each room, meaningful class discussion was impossible. The comparison group, on the other hand, was able to work in a room equipped with a cooling system. Their teacher reported that it was not uncomfortably warm, and that they did not have to deal with the noise of fans.

The first phase of the unit, the section on the blackbirds, was also impaired by an outside factor. The year that the unit was taught, the blackbirds were not nearly as numerous as they had been in previous years. Because of this many of the students did not see the relevance of the supposed problem, and they were not motivated to study it. To compensate for this, more could have been done at the outset to engage the students in the problem. For example, the teachers might have shown videos from locations in the community where the birds did assemble that year. They might have assigned the students to role play situations in which people in the community were frustrated by the black birds. These types of activities would likely have increased in the students an awareness of the situation and a greater desire to take ownership of the problem.
There are other factors which must be considered in future studies involving PBL. One element is class size. C.V. Rudie (personal communication, October 2, 1997) stated that the effectiveness of inductive discussion tends to decrease with larger groups. The problem-based learning class sizes were 27 and 28, compared to 21 and 22 in the traditional classes.

The early time of the year that the unit was taught might also have reduced the effectiveness. Because the teachers did not know their students as well as they would have known them later in the semester, various problems arose among group members which may otherwise have been avoided through different groupings or activities. Furthermore, a foundation of student trust in teachers needs to be laid prior to introducing a teaching strategy that is unfamiliar to students. This trust was not yet fully established in the early part of the semester, causing some students to resent learning activities that they were unaccustomed to doing.

Since the traditional group also studied their unit early in the school year, it might be debated that the timing of the unit should not be considered a factor in the effectiveness of the unit. However, under the traditional approach, opportunity for building positive relationships among students and teachers is not a prerequisite for learning because the focus tends to be more textbook-centered rather than student-centered.

Since PBL was new to the students in the experimental group, more work should have been done to get them ready to learn in this way. Up to this point in their schooling the students had done most of their learning under a more deductive approach. The newness of the PBL process and the lack of student preparation for handling it proved detrimental in all three variables.

Student attitude, for example, suffered because many of the children expected more guidance from their teachers. Even though the passive style of learning that one experiences under the traditional approach may not be overly enticing, it certainly feels
safer than being required to take responsibility for one's own learning. Therefore, the attitude variable was affected.

The problem-solving steps might also have been taught more explicitly. Simply leading the class through the five steps in each problem was perhaps not enough for most of the students to catch the significance of each stage in the process.

And finally, in order for knowledge of content to occur, students must see the importance of searching and studying the material as they work out solutions to their problems. Although many of their presentations in the unit were creative, the students were seldom able to give informed reasons for their solutions.

For these reasons PBL did not prove effective in this study. Given current knowledge of middle school students, however, PBL would seem appropriate at this level. For example, peer relationships become extremely important during adolescence. Because of this, middle school students tend to learn and develop best in situations where they can interact with other students, such as under the PBL method. PBL, when performed in an effective manner, also provides an environment that feeds the curiosity and affirms the creativity of children. Finally, in order for effective learning to occur, students must take ownership of their learning. This is more likely to happen under teaching methods that involve the children in real issues and problems.

Inclusion of PBL in one's methodology also exhibits a more holistic view of science. Beyond simply a body of definitions and facts, science is a tool. It offers a method for developing the creation; a guide for struggling with issues. Many Christian schools want their students to be knowledgeable. However, they also desire their pupils to develop the earth and to struggle with problems in a way that glorifies God. Problem-based learning provides an avenue for these activities to be practiced within the curriculum.

Certain factors, however, must be considered in future studies involving PBL in the middle school. Smaller class size and a calm, comfortable environment where
students can hear each other may have a more positive effect on PBL where whole class discussions are concerned. More study needs to be done on how to present a problem in a way to ensure that the students will be engaged. A positive classroom atmosphere where mutual trust among students and teachers has been established is also necessary for the learning to be effective. Because the approach involves a great deal of collaboration among students, the teacher needs to be acquainted with the special abilities and needs of all the children before embarking on a unit with PBL. And finally, the importance of preparing students for learning in ways that are unfamiliar to them cannot be overstated.
References


Appendix A - Attitude Toward Science Measure

Attitude Toward Science

Name: ________________________

Please use this scale to respond to the following statements:

SA -- Strongly agree
A -- Agree
N -- Neither agree nor disagree
D -- Disagree
SD -- Strongly disagree

(Circle one choice.)

(1) SA A N D SD  During science class, I usually am interested.
(2) SA A N D SD  I do not like science, and it bothers me to have to study it.
(3) SA A N D SD  I would like to learn more about science.
(4) SA A N D SD  If I knew I would never go to science class again, I would feel sad.
(5) SA A N D SD  Science is interesting to me and I enjoy it.
(6) SA A N D SD  Science makes me feel uncomfortable, restless, irritable, and impatient.
(7) SA A N D SD  Science is fascinating and fun.
(8) SA A N D SD  Science is a topic which I enjoy studying.
(9) SA A N D SD  I feel a definite positive reaction to science.
(10) SA A N D SD  Science is boring.
Appendix B - Problem Solving Pre-Test and Post-Test

The students will be instructed not to solve the problem, but to write a strategy for solving the problem. If the students are confused about the activity, they may ask questions for clarification, but the instructors will not be allowed to provide them with hints or examples. The groups will be provided 15 minutes to complete the task. The problem statements and the directions for the pretest and posttest are written below:

Directions: First read the problem. Then determine what steps you think the people should take in finding an answer to the problem. Do not try to solve the problem for them or tell them what you think the answer is. Only write down what you think the people in the problem should do to figure out how to solve their problem.

Pretest: A number of trees in a certain town have been dying in recent years. The residents are puzzled and unhappy. What do you think the town should do?

Post test: The number of fish in a certain lake have been decreasing in recent years. The people who usually fish in that lake are confused and disappointed. What do you think they should do?

Assessment

A number will be assigned to each student. The students will use this number to identify themselves on their tests. After the students have taken the tests the steps listed by each student will be categorized according to the five steps given by Parnes (1966, cited in Gallagher et al., 1992): fact-finding, problem-finding, solution-finding, implementation, evaluation. The researcher and a co-rater not involved in the learning unit will first categorize the results individually and then come to a consensus on the category for each step. The category "other" will be used for responses which do not fit within any of the five problem solving categories.

Since the study will focus on whether or not students use problem-solving steps a dichotomous coding will indicate the inclusion or exclusion of problem solving steps. For example if a student does not include "fact finding," a code of "0" will be assigned.
If a step is included one or more times, a code of "1" will be assigned. So, if a student lists one problem finding step, three solution finding steps, and two implementation steps, the coding for that student will be: fact finding = 0, problem finding = 1, brainstorming = 0, solution finding = 1, implementation = 1, and evaluation = 0.
Appendix C - General Concepts of Ecology Test

Name: __________________________

Multiple choice: Please read each question and all of the answers carefully before writing the letter of the best answer in the blank.

1. A population is...
   a. all of the different living things in an area.
   b. all of the ecosystems in the same region of the earth.
   c. all of one type of thing living in an area.
   d. all of the biomes on earth.

2. An area with similar plants and animals and similar climates is called...
   a. an ecosystem.
   b. a biome.
   c. an ecosphere.
   d. a community.

3. The tundra is...
   a. a treeless area near the North Pole.
   b. a type of grassland found in Australia.
   c. a hot place that has a very dry climate.
   d. a place where only evergreen trees grow.

4. The climate of the taiga...
   a. is warm and humid -- fit for many different kinds of animals and plants.
   b. includes hot summers and cool winters.
   c. extremely cold year around.
   d. milder (warmer) than that of the tundra.

5. Animals often found in a temperate deciduous forest might be:
   a. zebras, ostriches, lions, vultures, and antelope.
   b. snakes, lizards, jackrabbits, and kangaroo rats.
   c. squirrels, rabbits, foxes, deer, raccoons, and small birds.
   d. caribou, snowy owls, moose, and bobcats.

6. Which biome is home to more species of animals than any other place?
   a. taiga
   b. tropical rain forest
   c. desert
   d. temperate deciduous forest
7. Which combination of living things would most likely live in the marine biome?
   a. algae, diatoms, giant kelp, lobsters, seals, and clams
   b. algae, giant kelp, sea horses, trout, and carp
   c. lilies, elodea, muskrats, and beavers
   d. diatoms, algae, seaweed, beavers, muskrats, and crayfish

8. What is a biotic factor?
   a. any nonliving thing that affects the ecosystem.
   b. any living thing that affects the ecosystem.
   c. any living thing that eats other living things.
   d. any nonliving thing that is eaten by other living things.

9. What would be an example of an abiotic factor?
   a. fish          b. carnivore
   c. sunlight      d. plant

10. In an ecosystem detrivores are the organisms that...
    a. produce oxygen.
    b. change water and oxygen into sugar.
    c. feed on dead plant and animal matter and animal waste.
    d. control populations by eating plants or other animals.

11. What is carrying capacity?
    a. the amount of rain water that any type of soil can hold.
    b. the number of energy calories a plant can produce.
    c. the amount of air that earth needs for living things to survive.
    d. the number of a population that an environment can support.

12. What would happen to the number of spiders in a community if the number of flies went up?
    a. The number of spiders would go up.
    b. The number of spiders would go down.
    c. The number of spiders would stay the same.
    d. The number of spiders would first go down, then level off.

13. How do plants get the nitrogen they need?
    a. The only way is for humans to give it to them in fertilizer.
    b. Bacteria in the ground turns it into a form plants can use.
    c. They take it in through their leaves.
    d. Through a process called photosynthesis.

14. What is the only organism that can take the sun's energy and turn it into food?
    a. carnivores          b. plants
    c. herbivores          d. decomposers
15. What happens to energy as it gets passed along the food chain?
   a. Living things use about 90% of it and store 10%.
   b. Living things use about 10% of it and store 90%.
   c. Living things store all of it so that it can be passed to the next living thing.
   d. Living things use all of it; the next living thing has to start over.

16. Parasites...
   a. get their food from another thing that they live on or in.
   b. kill and eat their food.
   c. cooperate with other living things to meet their needs.
   d. live only in animals.

17. Which is an example of cooperation?
   a. bears and fish
   b. herder ants and aphids
   c. cardinals and sparrows
   d. two spruce trees living close to each other

18. What are cultural factors?
   a. things which animals do that get in the way of human activity.
   b. things that plants do which provide for the ecosystem.
   c. things that animals and plants do that limit the sizes of populations.
   d. things that humans do which affect ecosystems.

19. How have pipelines affected the tundra?
   a. They have leaked oil which is destroying the permafrost.
   b. They have made it possible for animals to be transported very quickly.
   c. They have made it difficult for caribou to migrate.
   d. They have caused the moss and lichens to die off.

20. Although plowing is sometimes necessary, what can be a problem with it?
   a. It loosens the top soil so that it can easily blow away or wash away.
   b. It ruins the homes of worms and sow bugs.
   c. It makes it difficult for birds to find the small animals that they hunt.
   d. It doesn't allow rain water to drain into streams and rivers.
Appendix D #1 - Letter Seeking Informed Consent from Parents of Experimental Group

Department of Graduate Education  
Dordt College  
Sioux Center, IA  51250

August 18, 1997

Dear Parent:

The Department of Graduate Education at Dordt College supports the practice of informed consent and protection for people participating in research. The following is provided for you to decide whether you will allow information regarding your child's progress in a particular teaching unit to be used in my research.

I am testing the effectiveness of an instructional technique during an upcoming ecology unit in my science class. Your sixth grade child along with the other sixth graders will be taught under this teaching method. Some tests on attitudes toward science, problem-solving ability, and knowledge about ecology will be given at the beginning and at the end of the unit. Hopefully, your child's learning will be enhanced under the new teaching method. However, should the class learn significantly less information under the new method, the information will be re-taught to the sixth grade class in the more traditional method so that the learning is not lost.

Your child's participation in the tests as well as the test scores are solicited but strictly voluntary. We assure you that your child's name will not in any way be associated with the research findings. The information will be identified only through a code number. The tests related to this study will not be graded, nor will the scores of these tests be used in evaluation for the report card.

If you would like additional information concerning this study before or after it is completed, please contact one of us by phone or mail. Unless you return this form indicating that you would not want your child's scores used in the study by __________, we will assume that your permission has been granted. Thank you very much for your time, and we appreciate your interest and cooperation.

Sincerely,

Alan Bandstra  
Teacher  
(712) 722-0777

Dr. Rick Eigenbrood  
Professor  
(712) 722-3771
Appendix D #2 - Letter Seeking Informed Consent from Parents of Comparison Group

Department of Graduate Education
Dordt College
Sioux Center, IA 51250

August 18, 1997

Dear Parent:

The Department of Graduate Education at Dordt College supports the practice of informed consent and protection for people participating in research. The following is provided for you to decide whether you will allow information regarding your child's progress in a particular teaching unit to be used in my research.

I am collecting data on the progress of sixth graders during an upcoming science unit on ecology. The sixth grade class will be given some tests on attitudes toward science, problem-solving ability, and knowledge about ecology at the beginning and at the end of the science unit. No changes will take place in the manner or method of your child's instruction.

Your child's participation in the tests as well as the test scores are solicited but strictly voluntary. We assure you that your child's name will not in any way be associated with the research findings. The information will be identified only through a code number. The tests related to this study will not be graded, nor will the scores of these tests be used in evaluation for the report card.

If you would like additional information concerning this study before or after it is completed, please contact one of us by phone or mail. Unless you return this form indicating that you would not want your child's scores used in the study by_______, we will assume that your permission has been granted. Thank you very much for your time, and we appreciate your interest and cooperation.

Sincerely,

Alan Bandstra
Teacher
(712) 722-0777

Dr. Rick Eigenbrood
Professor
(712) 722-3771
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Results of the Problem-Solving Pre-Test and Post-Test for both the Experimental and Comparison Groups

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Table 3
Results of the Knowledge Pre-Test and Post-Test for both the Experimental and Comparison groups

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VITA

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