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Rebecca's in the Dark: A Comparative Study of Problem-Based Learning and Direct Instruction/Experiential Learning in Two 4th-Grade Classrooms

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Abstract

Seeking improved student performance in elementary schools has led educators to advocate inquiry-based teaching approaches, including problem-based learning (PBL). In PBL, students simultaneously develop problem-solving strategies, disciplinary knowledge bases, collaborative skills, and dispositions. Research into the efficacy of PBL in elementary school settings is in the seminal stage and reveals mixed results. In this pilot study, 4th graders receiving PBL in science were compared with a corresponding group receiving the same instruction in thematic format. Using a quasi-experimental design, the researchers investigated students' knowledge of content, stereotypical images of scientists, time-on-task, and transfer of problem-solving skills.

Introduction

> *Lunch is over, the afternoon routine has started, and the 4th-grade students in Ms. W.'s classroom are slightly restive as they await the day's science lesson. However, the unexpected appearance of a visitor in their doorway creates a ripple of anticipation. Their visitor is a young woman, Rebecca, who wants to discuss a problem with the class. She is soon returning to her cold, snowy northeastern college town for the winter term. During last year's winter semester, several severe storms caused the university to repeatedly lose electrical power. While the university's generators provided enough electricity for heat, students were severely limited in their use of lights. The young woman needs a way to study at night, regardless of the power shortages that may occur. Unless the 4th graders can help her, Rebecca may remain "in the dark" and her grades may suffer. Thus begins a problem-based learning (PBL) unit on electricity entitled "Rebecca's in the Dark!" The 4th graders have received a challenge with real-life implications. What science concepts must they understand in order to help Rebecca?*

These 4th graders have been introduced to problem-based learning (PBL), a teaching/learning experience that provides students with problems before they receive any instruction. The problem provides the context for an in-depth investigation of core content (Checkley, 1997). This technique turns instruction "topsy-turvy" by having students contend with complex issues before establishing an in-depth knowledge base. Teachers help students determine what they already know, what they need to know, and where they can best find necessary information. Students assume the roles of scientists as they seek to find solutions to the problem under consideration. Class collaboration becomes vital as the students share information and work toward problem resolution. The role of the teacher becomes one of tutor or coach, helping the students take responsibility for their own learning (Stepien & Gallagher, 1993).

The use of PBL in professional education started in medical schools as early as the 1960s (Barrows, 1996). It has since been used in the education of engineers, lawyers, managers, architects, teachers, and other professionals (Boud & Feletti, 1991; Bridges & Hallinger, 1992, 1995; Kain, 2003), but it remains controversial. Proponents of PBL argue that it engages learners, promotes higher order thinking, and is effective in conveying factual information (Dods, 1996). Critics contend that PBL emphasizes thinking skills to the exclusion of course content (Dods, 1997).

Historically, a large percentage of the research base concerning PBL comes from the medical field. Three major reviews of the literature on the effectiveness of PBL instruction for medical students are considered seminal and are often cited when examining the pros and cons of PBL. These reviews, all done in 1993, revealed mixed outcomes and effects. Vernon and Blake (1993) concluded that results generally support the superiority of the PBL approach over more traditional academic methods due in part to higher levels of student satisfaction with their learning environment. Albanese and Mitchell (1993) found that PBL was more nurturing and enjoyable and that PBL students performed as well as and sometimes better on clinical examinations and faculty evaluations. They also concluded that PBL students showed gaps in their cognitive knowledge base, however. Berkson (1993) concluded that the PBL graduate was virtually indistinguishable from his or her traditional counterpart. Two recent reviews of the medical education literature on PBL attested that PBL had a positive effect on student skills and a negative effect on knowledge (Van den Bossche, Gijbels, & Dochy, 2000) and that there was no consistent evidence that PBL is superior to other educational strategies in improving doctors' knowledge and performance (Smits, Verbeek, & de Buisonjé, 2002). Results of a longitudinal study of PBL instruction for students in business, marketing, and nursing at Alverno College found that problem-solving skills were enhanced (O'Brien, Matlock, Loacker, & Wutzdorff, 1991). Bridges (1991) and Woods (1996) found positive results regarding school administrators and chemical engineering students using PBL-based instruction.

PBL has also been used in the training of preservice elementary science teachers. Both Watters and Ginns (2000) and Peterson and Treagust (1998) provided authentic and meaningful teaching scenarios for their science education students to solve as part of their elementary classroom practicum work. Peterson and Treagust (1998) found that their participants enhanced both their knowledge base for teaching science and their pedagogical reasoning ability through the use of a PBL approach. Watters and Ginns (2000) found that engaging in the PBL approach gave their preservice teachers greater confidence in their ability to teach science and in their ability to facilitate student-centered instructional strategies.

Research into the efficacy of PBL in public school settings is still in the preliminary stage. Gallagher and Stepien (1996) found that secondary students using PBL in American studies did as well on multiple-choice tests as students using a traditional model of instruction. The PBL students also showed a better depth of understanding of the content. A study by Dods (1997) analyzed the performance of students in a biochemistry course using PBL. The PBL students were found to have content knowledge about equal to those in a traditional lecture course. The PBL students did, however, retain more of the information, and they demonstrated a greater depth of understanding of the material. A study of 10th-grade Earth science students corroborated that PBL instruction improved their knowledge of the material as measured on an achievement test as compared to their peers in more traditional classes (Chang, 2001). High school students using PBL in biology, chemistry, and Earth science classes outscored their peers on 44% of the items on the National Assessment of Educational Progress (NAEP) science test given during their 12th-grade year (Schneider, Krajcik, Marx, & Soloway, 2002). Gordon, Rogers, Comfort, Gavula, and McGee (2001) used PBL with an urban minority middle school population. These students showed increased academic performance in science and improved behavior ratings over a two-year period. Liu, Hsieh, Cho, and Schallert (2006) also found that middle school students had a better understanding of science concepts and felt more confident about being successful learners after they completed a computer-enhanced PBL unit.

Differences concerning both the precise definition of PBL and the variety found in its methodological implementation have made measuring PBL outcomes difficult. In order to effectively evaluate the educational impact of PBL, the Project on the Effectiveness of Problem Based Learning (PEPBL) has established criteria for defining this instructional model as follows:

- Curriculum is organized around problems rather than disciplines, with an emphasis on cognitive skills as well as knowledge.
- The learning environment uses small groups, active learning, and independent study, and it is student centered. Teachers are facilitators, providing knowledgeable structure for the learners.
- Outcomes focus on skills development and motivation, as well as abilities, for lifelong learning. (Newman et al., 2003)

These criteria are being used to reevaluate previous studies of PBL and to conduct a randomized PBL field trial with students in nursing education. Data analysis is currently underway, and the results of this extensive study should further clarify the research on the effectiveness of PBL.

Despite the inherent difficulties in quantifying the results of PBL, the search for improved student learning in all areas of the public school curriculum has led educational reformers, practitioners, and researchers to advocate its use (Kain, 2003; Savoie & Hughes, 1994; Stepien & Gallagher, 1993; Stepien, Senn, & Stepien, 2000; Wiggins & McTighe, 1998). PBL is utilized as a method to promote students' construction of knowledge through inquiry at the K-12 level. PBL is a compelling example of a constructivist approach to learning. Scholars such as Dewey (1938) and Gagne (1965) have long advocated this approach. Dewey (1938) emphasized the necessity of providing educational experiences that were relevant to students through the use of problem-based instructional strategies. Gagne (1965) noted that problem-based instruction was particularly effective in developing science concepts. Science standards adopted by the American Association for the Advancement of Science (AAAS) (1993) and the National Research Council (NRC) (1996) not only identified what content students should know and understand, but they also identified what instructional methods should be used to improve student learning. Their recommendations included student-centered, inquiry-based practices that encourage a deep understanding of the science that is embedded in the everyday world. The fact that PBL features real-life problems as a basis for instruction, forcing students to apply their existing knowledge and stimulating them to do investigations in order to satisfy their "need to know" (Gordon et al., 2001) makes it a useful model for public schools implementing these standards.

Research Questions

The promise of PBL is appealing to public school educators who want to see their students become curious, thoughtful, and motivated learners who can work collaboratively to solve problems. As stated by Kain (2003), “Given that PBL has a record of success in sparking such curiosity and motivation, it is well worth considering as another tool to engage students” (p. 5).

The authors’ search for a research validated model that would promote inquiry and allow an integrated approach to teaching science at the elementary school level led them to explore PBL (Bartels, 1998; Edens, 2000; Gallagher & Stepien, 1995; Krynock & Robb, 1999). A review of the literature, while informative at the middle and high school levels, revealed considerably less research on the use of PBL at the elementary school level. Therefore, this investigation was designed as a pilot study to examine the efficacy of PBL with younger learners.

Fourth graders receiving PBL in science were compared with a corresponding group who received the same instruction in a direct instruction/experiential format. The curriculum content was based on the following 4th-grade competency goal from the 2004 North Carolina Standard Course of Study (NCSCOS) (Public Schools of North Carolina, 2004): “The learner will make observations and conduct investigations to build an understanding of magnetism and electricity” (p. 1). This goal is aligned with the National Science Education Content Standards for K-4 Physical Science (NRC, 1996).

Specific NCSCOS objectives taught during the two-week set of lessons included the following:

3.03 Design and test an electric circuit as a closed pathway, including an energy source, energy conductor, and an energy receiver.
3.05 Describe and explain the parts of a light bulb.
3.06 Describe and identify materials that are conductors and nonconductors of electricity.
3.08 Observe and investigate the ability of electric circuits to produce light, heat, sound, and magnetic effects.
3.09 Recognize lightning as an electrical discharge, and show proper safety behavior when lightning occurs.

This pilot study examined the following research questions:

- Is PBL more effective than a direct instruction/experiential model in increasing content knowledge?
- Does PBL result in increased retention of information over time?
- Does PBL affect students’ stereotypical images of scientists?
- Does PBL result in higher levels of time-on-task than a direct instruction/experiential model?
- Does PBL facilitate the transfer of problem-solving skills to other situations?

Methodology

Setting and Participants

The school site for the study had a population which included 31.7% Hispanic students, 26.7% African-American students, and 6.0% other minorities. Eighteen percent of the students were non-native English speakers. Eighty percent of students received free or reduced-price lunches. The two 4th-grade classes chosen were representative of the school's population (see Table 1).

Table 1. Participants in the Study

Characteristics	Comparison Group ($n = 16$)	Experimental Group ($n = 17$)
Male	8	5
Female	8	12
Students with identified disabilities	5	2
Reading at grade level	6	10
Reading below grade level	10	7
English as a Second Language (ESL)	5	5

Both classes received science instruction daily for 45 minutes over a two-week period. The same university professor provided the lessons for both groups and covered the same science content. Tasks for both groups were similar and included the use of print, video, and computer resources as well as hands-on experiments, small group work, teacher-led discussions, and demonstrations. Both groups kept records of definitions, data collections, and experiment results in daily journals.

The experimental group's instruction differed from the comparison group in one aspect: the addition of the elements of PBL. For the purposes of the study, PBL followed the model defined by Howard (2002) and Long, Drake, and Halychyn (2004) for elementary school students. This model includes the following four steps:

1. *Engagement:* The problem is presented to the students and any roles are explained.

2. *Inquiry/Investigation:* It is determined what information students already know, what information they need to know, and how best to acquire this information.

3. *Problem Resolution:* Students analyze their options and decide on an action or a decision.

4. *Debriefing:* Students discuss not only the content they have learned and how it may be useful in new situations but also the processes involved in solving the problem.

Data Collection

Both researchers were present at each of the lessons. One researcher took the role of classroom instructor, while the other gathered data, including the administration of all assessments. The data collection included pre- and posttests of content knowledge, the Draw-a-Scientist Test (Mason, Kahle, & Gardner, 1991), interviews, and observations of time-on-task.

Content knowledge was assessed using a pre- and posttest that included 16 questions. Two posttests were administered. One test was given to all students on the last day of classroom instruction. The same test was administered to a random sample of ten students from each class four months later.

Students' attitudes about scientists were measured using the Draw-a-Scientist Test. Drawings were scored from 1 to 11 using the Indicators for the Scientist Stereotype (Mason et al., 1991).

At the end of instruction, interviews were conducted with five randomly selected students from each class. These students were given a hypothetical science problem and asked how they would solve it. Questions included the following:

1. If you had a problem, what would you do first? Then what?
2. When you have questions or don't understand something, what can you do to find answers?

Time-on-task was measured using the Wasik-Day: Open and Traditional Learning Environments and Children's Classroom Behavior Scale (Wasik & Day, 1977). Each student was observed once during the two weeks of instruction. The observation period was for ten consecutive minutes with data tabulated at one-minute intervals. Student behavior was categorized as either Appropriate Time-on-Task, Appropriate Transition, Inappropriate-Nonproductive, or Aggressive.

Data Analysis and Results

Content

Content knowledge was measured with a 16-item pre- and posttest (see Appendix) that reflected the NCSCOS objectives. The test required students to select correct multiple-choice answers, decide if statements were true or false, match vocabulary to definitions, and label diagrams accurately (see Table 2).

Research Questions

- Is PBL more effective than a direct instruction/experiential model in increasing content knowledge?
- Does PBL result in increased retention of information over time?

Table 2. Growth in Content Knowledge Comparison

	Mean		**Standard Deviation**		
Content Test (16 items)	**Comparison (*n* = 15)**	**Experimental (*n* = 14)**	**Comparison (*n* = 15)**	**Experimental (*n* = 14)**	***t*(df)**
Pretest	7.80	6.64	2.32	1.59	
Posttest	11.93	12.50	2.11	1.80	
Growth	4.13	*5.86	2.36	2.47	-1.85(27)*
Posttest (4 months later)	11.78	11.75			

$^*p < 0.05$

The effect size, (d) = 0.72, was in the medium range.

There was a slight difference in prior knowledge of electricity as measured by the 16-item content pretest in favor of the comparison group. The comparison group ($n = 15$) had a mean score of 7.80 as opposed to the PBL experimental group ($n = 14$), which had a mean score of 6.64. A *t*-test which compared growth in the content knowledge between the comparison and the experimental groups was significant ($t[27] = -1.85$, $p = 0.0375$).

Posttest scores were somewhat better for the PBL experimental group, with the comparison group achieving a mean of 11.93 and the experimental group achieving a mean of 12.50. Results of content posttesting done after a four-month interval were almost identical, with the comparison group scoring a mean of 11.78 and the PBL experimental group scoring a mean of 11.75.

Student Perceptions of Scientists

Students' stereotypical images of scientists were measured before and after the two-week period of science instruction using the Draw-a-Scientist Test (Mason et al., 1991). In this test, the child is given a blank sheet of paper and asked to draw a scientist. Children are allowed 15 to 30 minutes to complete their work (see Table 3). (Eleven points were possible; lower scores were less stereotypical and more realistic.)

Research Question

- Does PBL affect students' stereotypical images of scientists?

Table 3. Draw-a-Scientist Test

	Mean		Standard Deviation	
Test (11-point scale)	**Comparison (*n* = 15)**	**Experimental (*n* = 11)**	**Comparison (*n* = 15)**	**Experimental (*n* = 11)**
Pretest	3.29	3.70	1.62	2.18
Posttest	3.40	3.30	2.32	1.76
Pre self-portrait	3.00	1.00		
Post self-portrait	5.00	5.00		

The comparison group and the PBL experimental group generated some differences in mean scores on their Draw-a-Scientist Tests (Mason et al., 1991). On this test, higher scores signify more stereotypical images of scientists (e.g., drawings might include such elements as lab coats, flasks and bubbling liquids, robots, unkempt hair, and beards on males). The comparison group scored a pretest mean of 3.29 and a posttest score of 3.40, signifying a slightly more stereotypical attitude toward scientists after the unit of study. The PBL experimental group moved from a mean of 3.70 to 3.30, indicating somewhat less stereotypical attitudes about scientists after the PBL unit. Self-portraits (students portraying themselves as scientists) were more frequent for both groups after completing the science unit.

Time-on-Task Behavior

Time-on-task behavior was measured using the Wasik-Day: Open and Traditional Learning Environments and Children's Classroom Behavior Scale (Wasik & Day, 1977). Students were observed in random order. For each student, behavior was classified and tabulated according to the Wasik-Day time-on-task categories for ten consecutive minutes (using one-minute data collection intervals). All students were observed once during the two-week teaching period (see Table 4).

Research Question

- Does PBL result in higher levels of time-on-task than a direct instruction/experiential model?

Table 4. Time-on-Task Behavior

	Mean		Standard Deviation	
Behavior	**Comparison (*n* = 17) (%)**	**Experimental (*n* = 19) (%)**	**Comparison (*n* = 17) (%)**	**Experimental (*n* = 19) (%)**
Appropriate time-on-task	58.75	68.24	20.58	16.53
Appropriate transition	16.25	12.94	10.53	11.76
Inappropriate-nonproductive	24.38	18.82	14.99	15.67
Aggressive	0.00	0.00		

The PBL and comparison groups showed differences in time-on-task behavior as measured by the Wasik-Day Scale (Wasik & Day, 1977). The comparison group had an overall appropriate time-on-task behavior of 58.75%, an appropriate transition behavior of 16.25%, and an inappropriate-nonproductive behavior of 24.38%. No aggressive behavior was noted.

The PBL experimental group had an appropriate time-on-task behavior of 68.24%, an appropriate transition behavior of 12.94%, and an inappropriate-nonproductive behavior of 18.82%. No aggressive behavior was noted.

The experimental group displayed more appropriate time-on-task behavior and less inappropriate-nonproductive behavior than the comparison group. Appropriate time-on-task behavior was higher in the experimental group by approximately ten percentage points.

Problem-Solving Ability

In order to determine whether or not students could transfer problem-solving skills to another situation, five students from each class were randomly selected and interviewed during the week following the science instruction. They were presented with the following problem and questions:

> *Let's suppose that you had been visiting a pond every day, and you noticed that it was getting smaller and that there weren't as many birds, frogs, fish, and insects as there had been in the past. Mmm . . . This is a problem. How would you (as a scientist) think about solving this problem?*
>
> - *What would you do first?*
> - *Then what?*
> - *Then what?*

Student responses to structuring a problem solution fell into six categories as follows (see Table 5):

1. “Write down what you know.” “Use information you already know.” (Think about what you know)
2. “Ask people or the owner about the pond.” “Ask a scientist or water expert about the pond.” (Ask questions)
3. “Inspect the pond.” “Look around for drain pipes and water sources.” (Observe)
4. “Put more water in and measure it every day.” “Take water samples.” (Experiment)
5. “Count all the things that live there.” “Use the computer and look up ponds.” (Make a plan)
6. “Make a ‘science board’ [this is a reference to the KQHL Chart used in the experimental classroom] and think of a hypothesis.” (Hypothesize)

Table 5. Problem-Solving Skills

Interview Responses	Comparison Group (*n* = 5)	Experimental Group (*n* = 5)
Think about what you know	0	4
Ask questions	0	3
Observe	5	4
Experiment	1	2
Make a plan	0	1
Hypothesize	0	1
Total responses	6	15

Students were then asked,

When you have questions or don’t understand something, what can you do to find answers?

Student responses about how to find answers to their questions fell into these five categories (see Table 6):

1. “Ask a science teacher.” “Ask someone who probably knows.” (Ask experts)
2. “Visit a website.” “Use a computer.” (Search Internet)
3. “Go to the library and get books.” “Use encyclopedia.” (Read books)
4. “Observe outside.” “Create a graph of the pond.” (Experiment)
5. “Watch a videotape.” “See a movie/CD.” (Watch videos)

Table 6. Information Gathering Skills

Interview Responses	Comparison Group (*n* = 5)	Experimental Group (*n* = 5)
Ask experts	2	2
Search Internet	2	5
Read books	3	5
Experiment	0	2
Watch videos	0	3
Total responses	7	17

Four months after the initial science instruction, ten students were randomly selected from each class for interviews to determine if they had retained problem-solving skills. They were asked how they might solve the following problem scenario:

> *Let's suppose that your teacher has a cousin whose name is Ella. Cousin Ella left her pet rabbit in a cage on your teacher's doorstep this morning. She left a note asking your class to take care of her pet while she is out of town. She just bought the rabbit, so she hasn't left any instructions about how to care for it. This could be a problem. How would you, as a scientist, begin solving this problem?*

Student responses about how to find answers to their questions were again classified into five categories (see Table 7).

Table 7. Problem-Solving Skills (4 months later)

Interview Responses	Comparison Group (*n* = 10)	Experimental Group (*n* = 10)
Ask experts	6	10
Search Internet	6	9
Read books	10	9
Experiment	0	2
Watch videos	0	6
Total responses	22	36

Research Question

- Does PBL facilitate the transfer of problem-solving skills to other situations?

Although both groups had been exposed to the same curriculum content and teaching resources, the PBL group was more forthcoming in identifying problem-solving strategies and in enumerating the variety of resources available. Their responses, both immediately after the teaching period and four months later, were more varied, as well as more comprehensive, with a greater number of total responses than the comparison group.

Study Constraints

The researchers experienced a variety of constraints while working within the public school setting. The demands of high-stakes testing made the teaching of the science curriculum secondary to the teaching of math, reading, and writing. The researchers were therefore provided with a maximum of 45 minutes per day for a two-week period to conduct the study. Integration of science with other areas of the curriculum was also not a possibility in this time frame, nor was it feasible to work with ESL teachers and special educators to more adequately meet the needs of students with limited English proficiency or students with significant learning difficulties.

The instructor and the interviewer were experts on PBL and clearly had full knowledge of the instructional method each participant received. This could be construed as a limitation of the study and would be important to consider in future studies.

The classes were originally comparable in terms of students labeled as "high need" (i.e., those reading below their grade level and those who spoke English as a second language). Both classes were taught using an inclusion model, with 19 students being present in the comparison group and 21 students being present in the PBL experimental group. The PBL experimental group included an autistic student as well as a student who had just enrolled prior to the beginning of the study and spoke only Arabic. In addition, absenteeism, as well as pull-out programs, resulted in some students missing a significant number of lessons (i.e., three or more). These students were unable to be included in the final results in some components of the study.

Small student numbers and the constraints discussed previously made finding statistical differences in the results of this pilot study difficult. *T*-tests were applied to content retention, changes in students' stereotypical perceptions of scientists, and time-on-task behavior. Content growth for the PBL experimental group was found to be significant. Replicating the pilot study several times and aggregating the data would create results with more validity.

A strength of the pilot study was the quasi-experimental design that controlled several variables that are typically difficult to manage in real-world settings. Both groups were taught by the same instructor, used the same materials and activities, and were taught on the same days for the same amount of instructional time. Both classes were taught in the afternoons. The instructor was able to maintain the integrity of both pedagogies as evidenced by the comparable scores in content knowledge for both groups. The classes differed only in that the instruction in the experimental classroom was placed within the context of solving an authentic, real-world problem (i.e., the PBL experimental group).

Discussion

This pilot study's results indicate that PBL has promise in the elementary school classroom. Although some critics (e.g., Dods, 1997; Van den Bossche et al., 2000) suggest that PBL may result in a decrease in content knowledge, that was not the case in this study. The significant growth in the experimental group's content knowledge and the comparable content test scores in the comparison and experimental groups four months after the teaching of the unit suggest that content knowledge may not be compromised when using PBL.

Students in this pilot study who participated in PBL showed evidence of collateral learning. In his book *Democracy and Education*, Dewey (1966) states that, "We never educate directly, but indirectly by means of the environment" (p. 19). Through the PBL environment, students were indirectly challenged to reevaluate their scientific stereotypes. Previous research has documented the difficulty in changing students' stereotypical images of scientists as "white males in lab coats" (Buck, Leslie-Pelecky, & Kirby, 2002; Finson, 2003). The results of the Draw-a-Scientist Test indicated that the PBL experimental group had fewer stereotypical images of scientists at the end of the unit. In addition, a greater percentage of the PBL experimental group viewed themselves as scientists than the comparison group. This change in perception may be an indirect, but important, result of engaging students in authentic scientific tasks and in authentic scientific roles. Broadening students' images of scientists is a first step toward encouraging them to take the initiative to further their study of science, and it enables them to envision themselves in a science-related career. Although the numbers in this pilot study are small, this finding could be of importance, particularly in a population of students who are not often exposed elsewhere to a wide variety of role models and career options in the sciences.

Another aspect of collateral learning exhibited by the PBL experimental group students was their ability to generate more problem-solving strategies than their peers in the comparison group (15 students versus six students). They were also able to enumerate a wider variety of resources for answering questions (17 students versus seven students). The information explosion has made it difficult for educational systems to teach students all there is to know; it is therefore incumbent upon those in educational settings to encourage learners to ask good questions, find information, and systematically solve problems. Results of this pilot study indicate that PBL can help students gain expertise in the skills that will enable them to become lifelong learners.

The data recorded concerning student time-on-task behavior suggests that involvement in an authentic problem keeps students more engaged. This is an important finding because students learn more (assuming the task is appropriate and challenging) when their time-on-task behavior is higher (Bloom, 1974). Students in the PBL experimental classroom had 4.27 more minutes per 45-minute class session of time-on-task behavior than their comparison group. This would result in an additional 21.35 minutes of engaged science instruction per week, and an overall gain of 12.80 hours of science over the course of the school year.

According to Howard (2002), in PBL, students are able to simultaneously develop problem-solving strategies, disciplinary knowledge bases, collaborative skills, and dispositions. By organizing the curriculum around the completion of an authentic problem or project, PBL requires students to use the knowledge and skills they have acquired in meaningful contexts. This approach is aligned with recommendations of the AAAS (1993) and the NRC (1996) that indicate the need for teachers to develop communities of science learners in their classrooms. These communities should engage students in inquiry-based activities to encourage a deep understanding of science and to develop attitudes and social values conducive to science learning. The results of this pilot study suggest that using PBL as a vehicle for teaching science in the elementary classroom has the potential to address these recommendations.

Further research will be important in confirming the promise of this approach at all educational levels.

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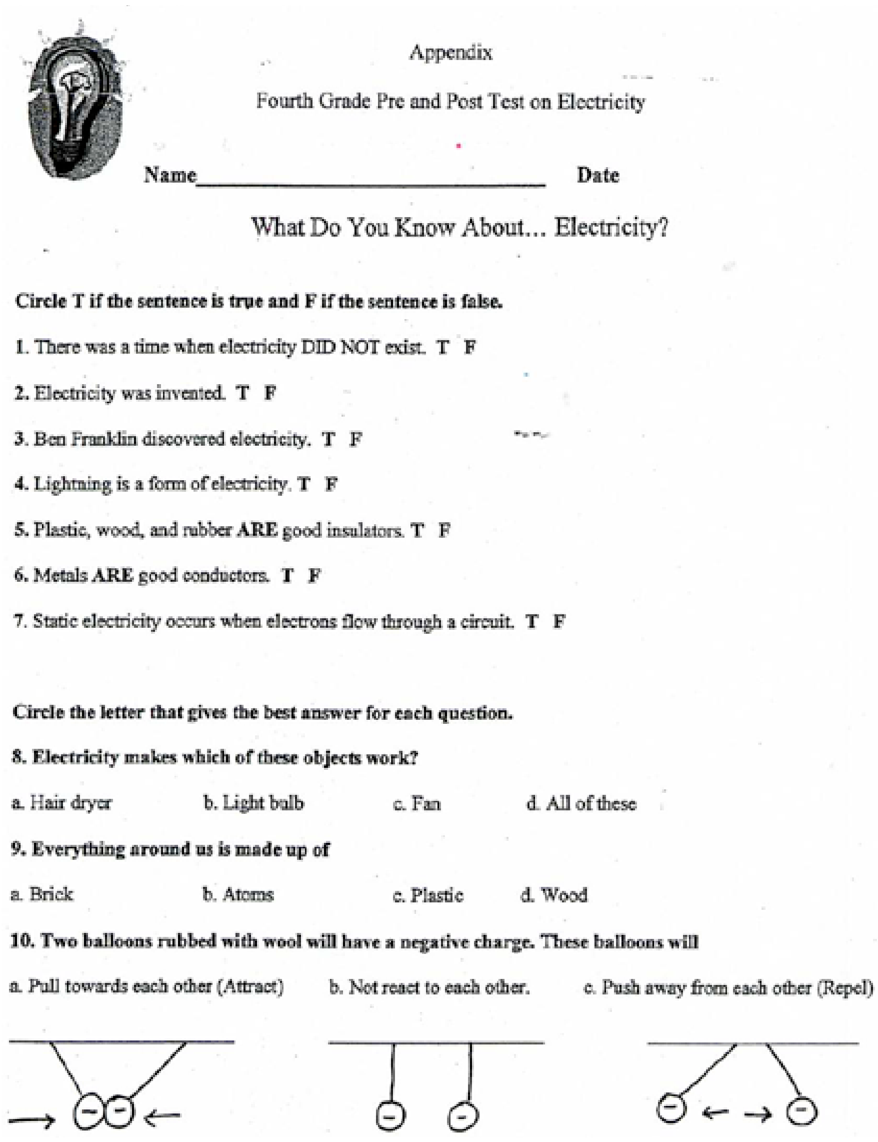


Appendix

Fourth Grade Pre and Post Test on Electricity

Name________________________________ **Date**

What Do You Know About… Electricity?

Circle T if the sentence is true and F if the sentence is false.

1. There was a time when electricity DID NOT exist. **T F**

2. Electricity was invented. **T F**

3. Ben Franklin discovered electricity. **T F**

4. Lightning is a form of electricity. **T F**

5. Plastic, wood, and rubber **ARE** good insulators. **T F**

6. Metals **ARE** good conductors. **T F**

7. Static electricity occurs when electrons flow through a circuit. **T F**

Circle the letter that gives the best answer for each question.

8. Electricity makes which of these objects work?

a. Hair dryer b. Light bulb c. Fan d. All of these

9. Everything around us is made up of

a. Brick b. Atoms c. Plastic d. Wood

10. Two balloons rubbed with wool will have a negative charge. These balloons will

a. Pull towards each other (Attract) b. Not react to each other. c. Push away from each other (Repel)

Write the letter in the blank that correctly matches the word to its definition.

Atoms contain the following:

A. Protons **B. Neutrons** **C. Electrons**

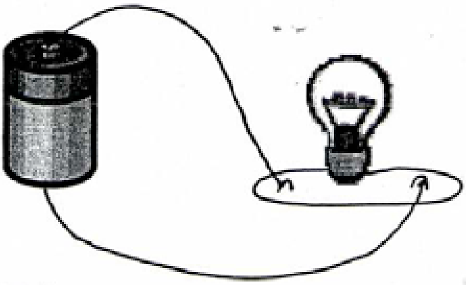
11. These particles have a positive (+) charge. ______

12. These particles have a negative (-) charge. ______

13. These particles have a neutral charge. ______

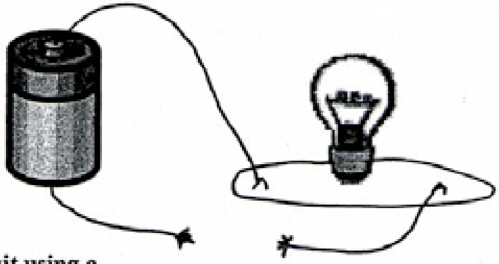
14. The following is an example of a(n)

Open Circuit Closed Circuit Static Electricity



15. The following is an example of a(n)

Open Circuit Closed Circuit Static Electricity



16. We can open and close a circuit using a

Switch Balloon Flashlight