Exploring the Environment: Problem-Based Learning in Action

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Abstract

A three-year study has been conducted in conjunction with the Exploring the Environment Project (ETE). Delivered over the World Wide Web (http://www.cotf.edu/ete), ETE uses problem-based learning as a means of engaging students in analyzing real-world events. Modules begin with a scenario dealing with issues such as deforestation, ozone depletion, or the plight of endangered species. Students report that they are more involved than usual when using ETE modules and they have better understanding of the concepts and problem solving. Most noteworthy is that the longer teachers are in the ETE Program, the more strongly students comment on positive attributes of this experience. Based on the analysis, teachers ability to implement a PBL environment is greatly enhanced through a well-structured, long-term program of professional development.

Medical schools became concerned when it became apparent that beginning medical practitioners knew many facts but had trouble putting them to use with real patients (Barrows, 1988). After assessing how doctors were trained, medical schools developed programs that immersed medical students in scenarios involving real or simulated patients. As the students engaged in new cases they usually did not have the "facts" or medical terms necessary to diagnose patients. What followed were student-directed investigations that required them to learn the "facts" or knowledge required to help the patient. This process became known as problem-based learning (PBL). PBL is now used in many medical schools and is coming of age in K-12 settings, especially since the draft and release of national standards.

The National Science Education Standards (NRC, 1996) cite a growing need for more advanced inquiry skills, such as being able to learn, reason, think creatively, solve problems and think creatively. The standards call for more than hands-on activities, suggesting that students must have "minds on" as well. Toward this end the standards are explicit in calling for inquiry-based environments. In these environments, "...students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations" (p. 2). The science standards elaborate on the planning and implementation of inquiry-based environments and call for change in schools so that teachers can design and carry out new ways of teaching and learning science.

Problem-based learning offers an ideal climate in which to address the cultivation of skills and knowledge called for by the National Science Education Standards. The PBL learning environment emphasizes active student learning, teamwork, and authentic assessment techniques. Working cooperatively, students engage in problem-based activities requiring them to formulate problem statements and to collect and analyze data. The PBL learning environment will raise questions such as: How do we know? What is the evidence? What is the argument that interprets the evidence? Are there alternative explanations or better ways of solving the problem? The aim should be to get students into the habit of posing such questions, examining data, analyzing, and framing possible explanations.

Teacher Skills

Teachers are viewed as key components in the development and implementation of any curricular reform. They must be well-prepared for the critical role they must play as professionals, particularly if schools are to continuously improve and adopt new skills associated with problem-based learning (PBL) and information-centered technology. The role of the teacher is changing dramatically as we move toward the twenty-first century. Teachers must keep up with an ever-expanding body of research-based information on effective teaching. The tradition of "teaching the way I was taught in graduate school" may be a notion of the past as educators poise for the continuous renewal and invigoration of their classroom strategies in light of new, upcoming technologies. Embedding new skills and strategies in the ETE project training and implementation seemed to be an effective way for teachers to acquire and retain multifaceted teaching practices. The training for these skills involved a specific pedagogy and a series of workshops interleaved with in-class implementation and reflection.

PBL research suggests increased student engagement, metacognitive growth, and long-term knowledge retention (Norman & Schmidt, 1992). A key to these benefits is teacher preparation (Myers, Botti, & Pompea, 1997). It takes time, patience and a willingness to accept risk and uncertainty to begin using inquiry-based classroom methods. Students, for example, will often be reluctant to take risks on their own—especially if they are used to having the objectives, assignments, and problems handed to them. If they traditionally take standard, objective tests, then students may dwell more on what they have to do to "get their grade" than in readily adapting to a PBL format (Myers, Purcell, Little, & Jaber, 1994).

Researchers recommend teachers receive professional development workshops dealing with classroom organization, cooperative learning strategies, discussion skills, and assessment strategies (Sharan & Sharan, 1992). Sharan and Sharan suggest establishment of a new classroom climate that encourages student interaction, and exchange of information between mixed-ability groups. In addition, Norman and Schmidt (1992) discuss the importance of teacher feedback during problem solving situations. Finally, research suggests that subject-matter expertise, commitment to students' learning and to their personal lives in an authentic way, and the ability to speak in language used by students are all ingredients for success in problem-based curricula (Schmidt & Moust, 1995). Schmidt and Moust also recommend teachers create an atmosphere supporting an open exchange of ideas and reflection.

Research tells us that the key to teaching with understanding is verbal interaction that enables teachers to monitor students' understanding of science concepts (Tobin, Tippins, & Gallard, 1994). Tobin et al. found that exemplary teachers effectively used the art of questioning and other verbal strategies to probe, stimulate thinking, focus student engagement, and uncover misunderstandings. When teachers hear students' verbalizations, they can place students in situations such that concepts and skills can be evaluated, demonstrated, talked about, or transferred to new scenarios. Penick, Crow, and Bonnstetter (1996) suggest that student discussions help develop logical mental structures, new ways of thinking, action, and answers to questions.

Based on research, and the ETE team's experience, providing teachers, both pre-service and in-service with the knowledge and skills necessary to managing and facilitating inquiry-based environments is a must (Myers, Botti, & Pompea, 1997). The National Science Education Standards (NRC, 1996) state that we have not done a very good job of preparing our teachers. We have to do better.

In the pages that follow we describe the Exploring the Environment Project's[1] design, implementation and evaluation.

Exploring the Environment

ETE is a four-year project whose goals were to demonstrated effective use of the World Wide Web (WWW), and to provide classrooms with remote sensing (satellite imagery) tools. The design team chose a modular approach and suggested PBL as the method for student engagement. Delivered completely over the WWW, ETE modules engage students in investigating real-world environmental problems. Typical scenarios involved deforestation, endangered species, natural hazards such as volcanoes and hurricanes, global warming, and ozone depletion. All modules began with a scenario.

The first module developed in the project was the Orting High School dilemma. Here is the scenario students receive from the web site (http://www.cotf.edu/ete, 1998).

> Business and community leaders in the city of Orting in Pierce County, population explosion. (Orting is only 30-40 minutes commuting time from the rapidly growing Tacoma and Seattle metropolitan areas.) However, Pierce County officials have refused permission to build the high school on county lands because they feel the location is hazardous. Geological surveys show that both Orting and the proposed high school site are on top of solidified mud flows that originated on the slopes of nearby Mount Rainier. Based on the location of older flows around Mount Rainier and on experience gained from observing mud flows during the 1980 eruption of Mount St. Helens, county officials argue that any new mud flow coming down the valley could easily destroy the high school and anybody who happened to be in it.

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[1] Exploring the Envionment was fully funded by NASA's Learning Technology Program, NASA CAN NCC5-107, http://iita.ivv.nasa.gov/iita1.html.

> County officials have also passed an ordinance forbidding high-density housing (like tract-home developments) on county lands, claiming that there are not sufficient roads out of the city to allow for emergency evacuation. The ordinance has upset local developers. City leaders counter that warning from a system of acoustic sensors (which has not yet been built) would give students enough time to evacuate the school, if necessary. On three occasions, the city has tried to pass a bond issue enabling the high school to be built on city lands but has not been successful.
>
> Representatives from both the city and the county have appealed to your company to provide them with the facts and potential risks of the situation and to recommend whether or not to build the high school.

A number of key points about this scenario and its use in a PBL environment bear elaboration. First, this is a real-world scenario. The Orting community actually had and continues to have a debate over whether or not to build this school. Second, students may know little or nothing about strato-volcanoes when they begin this module, but when they are finished, they will know a great deal about the risks and hazards associated with this type of volcano. Depending on the teacher's goals for this material, students are also likely to know about the other major types of volcanoes and how they differ from one such as Mt. Rainier. Third, there is no correct answer to this problem; whatever the students decide to do, they have to base their recommendation on information compiled during their investigation.

To aid students in their deliberations, the ETE team provided background readings about volcanoes. There is a great deal of information about Orting, to include maps, satellite images, and pictures of the Orting area. Also included is an activity that allows students to calculate the amount of material ejected from the Mt. St. Helens volcano. To reinforce that volcanoes can have significant impacts on people, an account of Mt. Vesuvius's 79 A.D. eruption by Pliny the Younger is enclosed, along with accounts from the Mt. St. Helens eruption.

In PBL teachers act more as facilitators than conveyors of information. The online ETE "Teachers Notes" provides teachers with the designers' goals and objectives for each module. There is also a section about how to implement problem-based learning. The notes provide teachers with some idea of where students might "go" with the problem; in this type of environment, students often surprise teachers by taking an innovative approach to a problem. Also included are experiences other teachers had in the module and ways the module may be modified, enhanced, or elaborated upon.

An important feature of the *Exploring the Environment* Project (ETE) has been the availability of teacher training workshops and teacher online support materials. For the past three years ETE developers have conducted week-long summer teacher workshops. The workshops and follow-up during the school year have afforded both teachers and ETE developers the opportunity to identify variables of successful implementation of ETE in a problem-based learning environment. Eight of the 50 ETE teachers attended the workshop for three summers, providing a longitudinal look at how teachers infused new methods and technological tools into their classrooms. The summer workshop concentrated on implementing PBL in classrooms and on how to use satellite imagery to support environmental studies.

METHODS

Subjects

The ETE project was evaluated in 50 schools over a three-year period. Participating teachers were chosen after submitting applications to participate in an alpha test. Teachers had to have World Wide Web access and agree to use problem-based learning methodology. Participants used the modules in a variety of classes, including biology, earth science, social studies, statistics, and chemistry. Students ranged from grades 9 through 12 and varied in background and pre-knowledge; 951 students were surveyed. Schools came from across the continental United States, representing urban, suburban, and rural settings. All but three of the schools used the ETE modules in elective classes.

Design
ETE developers used a variety of techniques to gather information concerning classroom use of its modules. Techniques include written products, classroom observations, teacher interviews, attitude surveys, and end-of-module questionnaires.

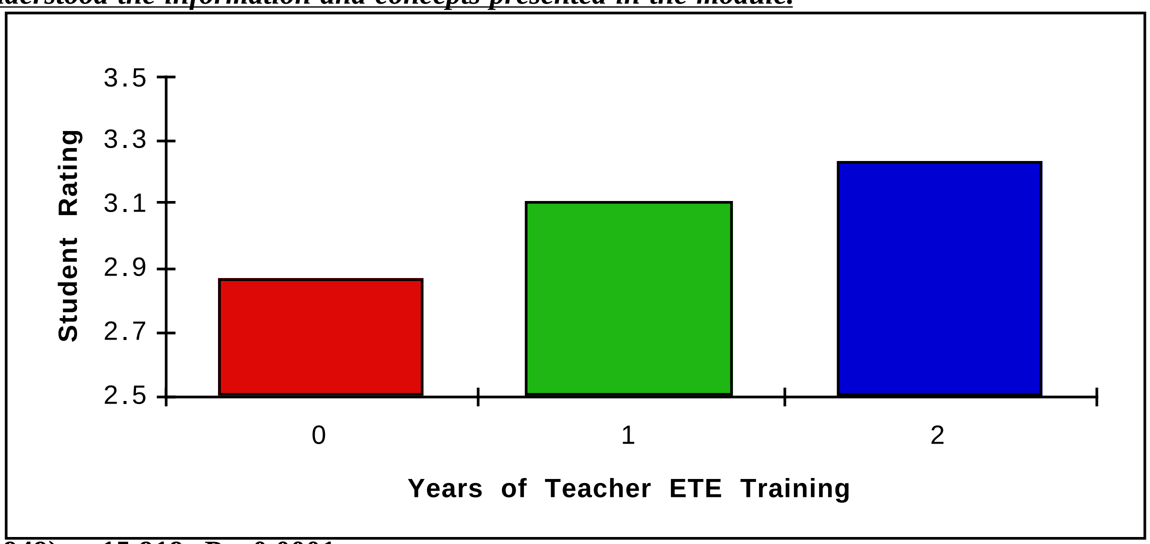
<u>Student end-of-module questionnaires with Likert measures</u>
Students completed a questionnaire that addressed issues relevant to the development of the modules. Examples include difficulties they have encountered, sections of the modules that were especially beneficial, and students suggestions for modifications. The end-of-module questionnaires contained Likert scale response forms with space for written elaboration. Using the variables of success identified over the past three years, investigators used ANOVA to determine whether there were significant differences in the students' ratings, based on the number of times teachers attended PBL training at the ETE summer workshops.

<u>Teacher end-of-module questionnaires and teacher interviews</u>
Teachers completed a questionnaire that addressed issues relevant to the implementation of the study. The questionnaires asked for replies concerning difficulties encountered, module design, and facilitation of problem-based learning. Teacher questionnaires were further supplemented by site visits or by telephone interviews. These questionnaires were surveyed for anecdotal information that illuminated findings from the ETE project.

Results

Understanding Information and Concepts
An important variable in the success of ETE modules is students' understanding of "complex issues." Understanding of complex issues was measured by examining the results of student self-reported, end-of-module questionnaires. Students provided Likert-scale agreement rankings of the statement, *I understood the information and concepts presented in the module.* A score of 1 indicated *Strongly Disagree;* a 4 indicated *Strongly Agree*. Investigators used ANOVA to determine whether there were significant differences in the students' ratings, based on the number of times teachers attended the ETE summer workshops. An examination of students' opinions related to the amount of ETE training of the students' teachers revealed an across-the-board increase in students' attitudes toward understanding of complex issues. The investigators found statistically significant differences across three groups of students whose teachers had had no years of training, one year, and two years of training (see Figure 1).

Student responses to question:
<u>I understood the information and concepts presented in the module.</u>

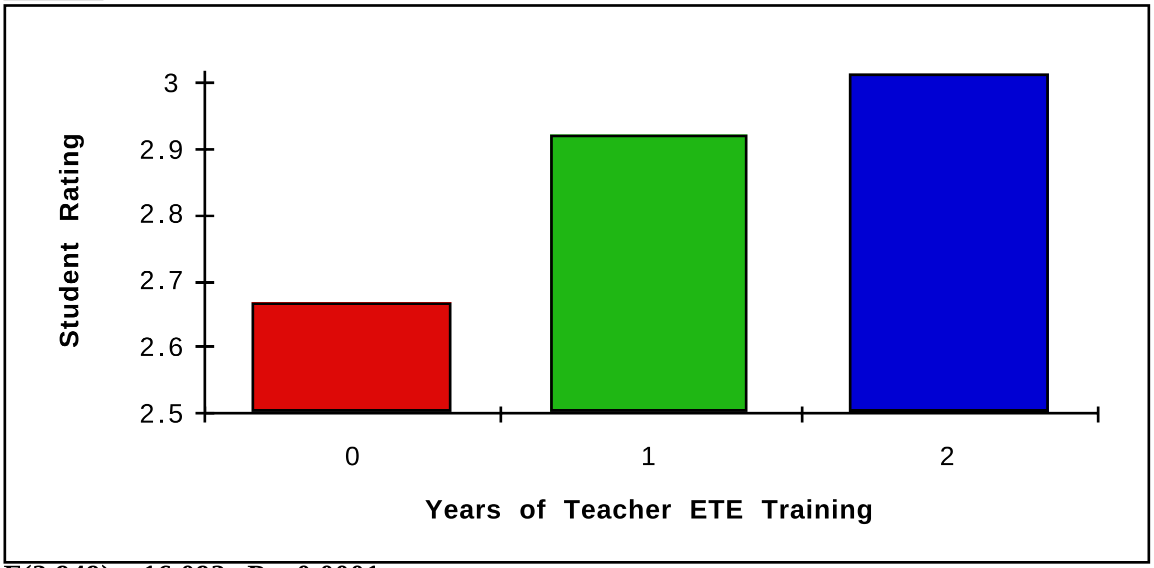


$F(2,949) = 15.919$, $P < 0.0001$

Figure 1

Understanding the Problem-Solving Process
Investigators were also interested in whether students' perceptions regarding their abilities to solve problems improved as a result of using the ETE modules and how this improvement, if any, was related to the amount of PBL training of their teachers. Students were asked to rank the statement, *I have developed a better understanding of the problem-solving process as a result of using the ETE module*. A score of 1 indicated *Strongly Disagree;* a 4 indicated *Strongly Agree.* An analysis of students' rankings of this statement on their end-of-module questionnaires indicated that students' perceptions of their understanding of problem solving improved as the ETE training of their teachers increased. Investigators found statistically significant differences across groups of students whose teachers had had no years of training, one year, and two years of training (see Figure 2).

Student responses to question #2:
I have developed a better understanding of the problem solving process as a result of using the ETE module.

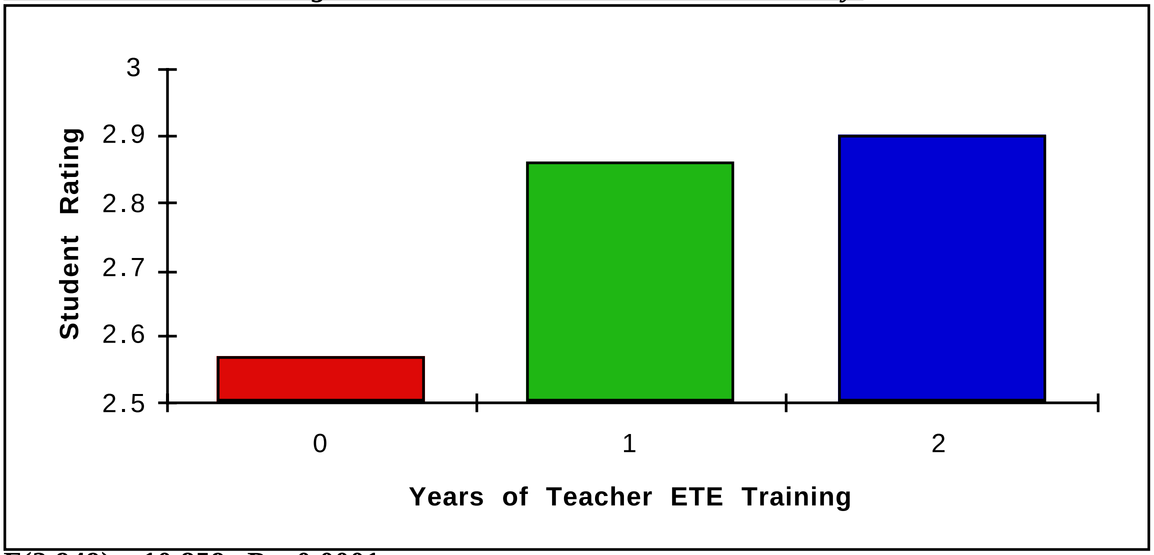


F(2,949)= 16.092, P< 0.0001

Figure 2.

Student Involvement
Analysis of end-of-module questionnaires on students' perception of their involvement while using an ETE module versus their involvement while using a non-ETE method of learning showed a statistically significant increase among students of teachers with one or two years of ETE training. Students were asked to rank the statement, *I was more involved using the ETE module than what I am normally*. A 1 indicated *Strongly Disagree*, while a 4 indicated *Strongly Agree.* As with the complex issues variable and the problem-solving variable, significant differences were found on this variable between groups of students whose teachers had had zero and one or two years of training (see Figure 3).

Student responses to question:
I was more involved using the ETE module than what I am normally:



F(2,949)= 10.859, P< 0.0001

Figure 3

DISCUSSION

The survey results of 951 students cited above suggests that the longer teachers are involved with problem-based learning through ETE summer, professional development workshops, repeated classroom use, and ETE module use, the more students feel they are involved, have a better understanding of the problem solving process, and understand the concepts presented in the PBL module. One student wrote: "[the ETE modules] taught me a great deal about remote sensing and problem-based learning. Now that I understand the process, I can apply it to other situations" (Thornburg, 1997).

Research states that through PBL use, students find learning more stimulating, develop critical thinking skills, become more self-directed learners and make better connections between learning and learning for life (Sage & Torp, 1997). These characteristics are in line with the students' survey results cited above. Amplification comes from a first-year ETE teacher who wrote:

> For a first try, it was great. I learned so much, and have already incorporated my new knowledge in plans for the next project. Student thinking, as evidenced by final reports and anecdotes seem to have been impacted. They wanted their reports to be sent to real agencies to influence policy. One group shared their finding about "tree-free paper" with COTF administrators, suggesting its use at NASA. One student used her knowledge during a discussion in another class (Hathorn, 1996).

Other teachers' commented favorably on student ownership of the learning experience, student motivation, and the integration of subjects, skills, and technologies. Even though it usually takes more time to implement PBL, teachers wrote positively concerning the experience; for example: "A positive and rewarding experience for both myself and the students involving a great deal of time, though it was time well spent" (Beckelheimer, 1996).

Teachers' confidence also appears to increase through multi-year workshops and experience. One writes: "The second time around proves much more successful. I used the problem solving more successfully. Now I am satisfied. Students were able to see how the Rift Valley problem is an Environmental problem having multiple aspects across the curriculum (Schroth, 1996)."

Last, a teacher in West Virginia who has been in the program for three years shares his thoughts about PBL and the ETE classroom environment.

> Participating with ETE has enhanced my students' proficiency in use of the scientific method. My students have also learned about problem-based learning and how it can be applied to real life situations. My students deal with real life problems everyday because they do projects in which they have to apply their skills and the ETE modules have helped out tremendously. The ETE program has also taught my students to think in detail and realize that there may be more than one solution to a problem. The modules have also given them some understanding of problems that exist throughout the world and some students have been able to relate them back to some problems that are occurring around the area in which they live (Powell, 1998).

EDUCATIONAL IMPORTANCE

The framework employed in the design of the ETE teacher workshops is derived from the works of Joyce and Showers (1980) and the National Science Education Standards (NRC, 1996). Both identified the components of teacher training that are essential to success and are embedded in the ETE project:

- Theory components are the rationale, theoretical base, and verbal description of an approach to teaching a skill or instructional technique. In many teacher workshops, it is not uncommon for <u>presentation</u> of theory to be the major, and in some cases, the sole component of the training experience. Presentation of theory can raise awareness and increase conceptual control of an area to some extent. Relatively few teachers, however, acquire skills or transfer this new knowledge into the classroom. Although classroom presentations to teachers are an important component, they usually not powerful enough to achieve impact beyond the awareness level.
- Modeling involves enactment of the teaching skill or strategy either through a live demonstration with children or adults, or through television, film, or other media. Modeling appears to have a considerable effect on awareness and some on knowledge. Demonstration also increases the mastery of theory. Participants better understand what is illustrated to them. For most teachers, however, modeling alone is unlikely to result in the acquisition and transfer of skills unless it is accompanied by other components. Research indicates that modeling needs to be a component of any training program aimed at acquisition of complex skills and their transfer to the classroom situations.

  The ETE team has been using high school students effectively in summer workshops. Students (usually four or five) arrive a full week before teachers so that the students learn the basics of PBL and the expectations encountered in PBL classrooms. During the first morning of the teachers' workshop the student group is presented a new scenario, then work on it for an hour while the teachers watch. For the rest of the week, the students provide the teachers a brief, daily report on their progress. This gives the ETE Team a chance to model the verbal strategies and reflection that are so important in PBL classrooms. On the final day of the workshop, the students present their recommendations and review their progress in a metacognitive vein. At the end of the experience, one students wrote: "It was an enlightening two weeks, and I don't think I've ever learned so much in such as short period of time" (Swanson, 1997). The students' live presentation allows teachers to reflect on the entire PBL process and to also discuss alternative assessment strategies.
- Practice involves trying out a new skill or strategy. When awareness and knowledge have been achieved, practice is a very efficient way of acquiring skills and strategies. While the students are busy engaging in their group investigation, the teachers are trying out PBL modules as well.
- Feedback can be self-administered, provided by observers, or given by peers and coaches. Feedback can involve learning a system for observing teaching behavior or providing an opportunity to reflect on teaching by using the system. It involves the provision of information about performance. It can be regular or occasional. Modeling followed by practice and comments can be very powerful in achieving skill development and transfer. During the workshops, teachers have the opportunity to give and receive feedback.
- Coaching for classroom application involves helping teachers analyze the content to be taught and the approach to be taken. This includes making specific plans to help students adapt to the

new teaching approach. Helping students adapt includes covering the skills recommended by Sharan and Sharan (1992).

The framework also contains elements that are involved in the design and implementation of effective teacher training that are patterned after the first three NRC professional development standards summarized as learning science, learning to teach science, and learning to learn.

The NRC professional development standards present a vision for the development of professional knowledge and skill among teachers. They focus on four areas:

- The learning of science content through inquiry.
- The integration of knowledge about science with knowledge about learning, pedagogy, and students.
- The development of the understanding and ability for lifelong learning.
- The coherence and integration of professional development programs.

> Reforming science education requires substantive changes in how science is taught, which requires equally substantive change in professional development practices at all levels. Prospective and practicing teachers need opportunities to become both sources of their own growth and supporters of the growth of others. They should be provided with opportunities to develop theoretical and practical understanding and ability, not just technical proficiencies. Professional development activities need to be clearly and appropriately connected to teachers' work in the context of the school. In this way, teachers gain the knowledge, understanding, and ability to implement the Standards. (pp 4-5)

ETE workshop presenters include experienced teachers who use technology and inquiry-based methods in their classrooms. Teachers go away with the tools necessary to implement inquiry-based methods and to effectively infuse technology into their classes.

Conclusion

This paper describes the ETE environment, its emphasis on PBL usage and the concerted effort to imbue teachers with the confidence, skills and attitude necessary to implement PBL in classrooms. PBL classroom use supports many of the variables necessary for effective learning. Students are deeply engaged, think critically, express more confidence in problem solving situations, and make connections between the classroom and everyday life. The ETE team often opines that it is much easier to deliver content, than it is to effectively facilitate a collaborative, reflective environment in which a great deal of questioning, probing and higher order thinking is occurring. Three years experience with the teachers and collecting classroom data tells us that most teachers new to PBL need a sustained, structured program of professional development and year-round scaffolding.

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