EXPERIENCES WITH PROBLEM-BASED LEARNING: VIRGINIA INITIATIVE FOR SCIENCE TEACHING AND ACHIEVEMENT

C. PHILLIPS, R. ZIMMERMAN, and A. MARTIN
York County School Division
Yorktown, VA 23692
rzimmerman@ycsd.york.va.us; amartin2@ycsd.york.va.us

Abstract

The Virginia Initiative for Science Teaching and Achievement (VISTA) provides high-quality professional development for teachers and administrators to enhance the quality of their science instructional programs. One emphasis of this program is helping teachers learn to implement Problem-Based Learning in the elementary science classroom. Problem-Based Learning (PBL) has the potential to produce significant positive outcomes for students, such as increased student engagement, and opportunities for in-depth critical thinking [1]. Teachers find PBL challenging because it does take additional time for planning and material acquisition, but experience has shown that the benefits outweigh these challenges. Setting clear goals, identifying specific learning objectives, and developing big questions that tie these together help increase the success of the unit. Additionally, administrators can help teachers succeed in implementing a Problem-Based Learning unit by understanding the dynamic nature of the PBL environment, providing flexibility with unit pacing, and setting aside time for refining, reflection, and revision of the unit.

Introduction

Teaching science seems simple, right? Actually, it is! After attending a summer professional development program for elementary teachers sponsored by the Virginia Initiative for Science Teaching and Achievement (VISTA), we now have a clearer understanding of research-based best practices in science teaching. We are two elementary teachers and a district science coordinator from a public school division in southeastern Virginia. The practical experience and instruction provided by the VISTA professional development program helped us understand why students need hands-on, real-world experience in order to learn significant science content. We discovered that learning science through inquiry develops critical thinking and engages students in learning unlike other instructional practices. Here is a brief summary of our experience with Problem-Based Learning, along with an analysis of the successes and challenges of implementing the unit.

A Unique Professional Development Experience

Training for VISTA began at the end of June when teams were assigned to a cohort of teachers from around the geographic region. Teachers engaged in instruction for a total of twenty days, over a five-week period during the summer. The first day was somewhat overwhelming because the room was filled with over fifty teachers from all over the area, and from all different grade levels. After about a week, everyone learned to work together, plan together, and gain useful feedback from each other's unique perspectives. The participants' weekly experience during the elementary teacher summer program is outlined below.

Weeks 1-2 — Learn about the VISTA program, and become a student yourself. Instructors engaged us in activities that modeled effective instructional strategies for teaching the nature of science. We greatly benefited from the peer interaction and getting to know one another during these first two weeks. During this time, we were assigned to a summer camp. Then, we began learning how to plan engaging lessons based on the Problem-Based Learning (PBL) format.

Weeks 3-4 — In the next two weeks, we became an instructor at a science summer camp for area students. We put into practice what we had learned throughout the training process, and experimented with new instructional strategies. A group of panel teachers observed and collected data on the instruction. Each teacher was assigned to a team and taught for two days. On our days off, we became part of the panel that observed and collected data on other assigned teachers. At the end of each day, we used discourse to discuss strengths and weaknesses. This was the moment when theory turned into practice as we learned how to improve the science instruction in our own classrooms. At the end of the camp, all students put on a culminating activity to present what they had learned to their friends and families.

Weeks 4-5 — When we were not observing or instructing at the camp, we were back in class. During this time, we had the opportunity to develop our own PBL unit while working with experts in both science and education. We had the pleasure of working with physics and biology professors from The College of William & Mary.

Problem-Based Learning: Theoretical Framework

Problem-Based Learning is a research-based instructional method that has been shown to increase student interactions and promote problem-solving skills [1]. With its origins reaching as far back as John Dewey in 1944, Problem-Based Learning focuses on students learning by doing the work in an authentic setting through solving real-world problems [2]. Students work collaboratively, which simulates experiences in the workplace and builds communication skills.

During this collaborative work, the teacher acts as facilitator to guide the students to the knowledge they need in order to solve a unique, open-ended problem [3]. Driven by the students' own need-to-know list, the classroom learning environment becomes student-centered and goal-oriented. Students that learn through problem-based methods tend to develop enhanced critical thinking skills and have higher intrinsic motivation to learn [4]. Introducing this instructional methodology to our grade 4 students created an atmosphere of excitement and intrigue for the students, but also took much thought and pre-planning.

Problem-Based Learning: Planning and Implementation

Planning for a Problem-Based Learning (PBL) unit takes time, careful planning, reflection, and revision. During the fall semester, our grade 4 students engaged in a playground design project. The students were asked the question, "How can you create a playground that is safe and fun for children with special needs?" This question initiated a cycle of scientific inquiry. Students were immediately engaged in thoughtful questioning. Using these questions as the foundation for the planning process, we developed lessons that would help achieve the goals of the unit. We focused on significant content that would drive each lesson, and provide students with the information they needed to solve the problem. At the beginning of each lesson, students engaged in a hands-on activity using real science equipment. These mini-lessons provided instruction in the significant content, while tying in themes from the Nature of Science. Engaging students in specific instruction regarding the nature of science was important to help students develop a clear understanding of the scientific process [5]. For example, students were asked the question, "How does the surface of a playground impact safety based on friction?" The students then completed an activity that helped them draw a conclusion about the question, and led them to determine how they wanted to build the floor of the playground. During the playground design process, our students engaged in numerous experiments. These experiments helped students understand that scientific knowledge is empirical and must be based on experimental data, a key aspect of the nature of science. To help students think critically about the topic, it was important to get them to think about safety for *all* children, including those with special needs. The students were taught a lesson on friction using real science friction boards, which helped focus on the significant topic of friction from the fourth grade Virginia *Standards of Learning*.

Similar lessons followed, with a culminating activity of building a model playground made for children with special needs. Students utilized Skype™ to communicate with an expert in playground safety, and used that information to further refine their project. Students then presented their final model to parents and members of the school board. This provided students an audience for the project, and allowed them to gain a sense of accomplishment from their hard work.

Successes with Problem-Based Learning

Increases in student engagement and the amount of critical thinking were two main areas of success with this project. Keeping students engaged in the big question helped ensure all students were involved in the process of solving the problem. The school where this unit was implemented has a high number of children with special needs requirements. This made the big question of playground safety for students with special needs relatable and engaging for the students. They also played the role of scientist as they engaged with hands-on experiments and activities. On many days, the learning truly felt like playing. Problem-Based Learning also made varying the instructional methods to meet the needs of diverse learners quite easy. One example of this was an experiment on the effect of different materials on the speed of objects going down the slides. Students rolled a marble down a slide and tested different materials to be the landing platform. The object was to figure out which landing material slowed the marble down the most. Students used that information to safely construct platforms for their model playground. Visual acuity, fine motor skills, and creativity were needed to successfully complete this experiment and, no matter what their learning style, all students were able to stay focused and engaged in the project.

Another success of the unit was the increase in opportunities for students to think critically. The professional development provided by VISTA on the Nature of Science and how to engage students in real scientific processes, helped us understand that Problem-Based Learning creates the platform for critical thinking to occur. The project's big question required students to be creative and logical in the construction of their playground. Near the end of the unit, they learned through the safety expert from the National Network for Playground Safety that equipment had to be a certain distance apart, and certain restrictions applied to wheelchair slides. At this point, students had already begun constructing their playground models. Students then had to incorporate the information they learned, and make necessary adjustments to their playground models. Students also engaged in critical thinking as they encountered experiments that had a different outcome than expected. In one experiment, students were testing the impact of falling on different materials (mulch, sand, rubber). The students thought that mulch would be the best material to use during their hypothesis. At the end of the experiment, they found that sand was actually better than the other materials they had tested. Students were required to form a reason for this or create another experiment to test, and re-think why their hypothesis was not accurate. Students realized that scientists change ideas and must re-test to get a more accurate result. Promoting critical thinking became natural as students engaged in achieving a solution to the proposed problem.

Overcoming Challenges with Problem-Based Learning

The biggest challenge in planning and implementing the PBL unit was finding the necessary resources. Planning for the first PBL unit took four hours a day for a week. After that, more time was spent gathering materials and resources, finding someone to communicate with on Skype™, and lining up an authentic audience for the student presentation. Another challenge encountered by project planners was underestimating the time needed to complete the project. With high-stakes testing just around the corner, it was tempting to skip lessons or shorten the project. Ultimately, time was found, but taking the time to create and implement such a large unit was very difficult. Although these challenges were tremendous, the project was implemented successfully with only a few modifications along the way.

Advice for Teachers

Many lessons were learned from the implementation of a Problem-Based Learning unit. The first was, keep it simple. In the beginning, a great deal of time was spent planning, but during the unit, adjustments were made to lessons and experiments to fit the schedule and materials available. Testing the experiments ahead of time with the available materials is essential. Several experiments did not work because the equipment selected was inadequate or the quantity of supplies was limited. Some real science equipment could not be substituted for normal classroom materials. Planning ahead and making a list of needed materials and sources for science equipment is essential. Another reason to keep it simple is because students are driving the solution to the problem. Teachers will not be able to pre-plan for every great student idea. For example, when doing one experiment on kinetic and potential energy, the students came up with another idea for their playground involving potential and kinetic energy. So, another experiment was added to help students incorporate this component into their model. This helped us learn that the project does not have to be as big as some might think. We have since developed several more PBL units for other topics. These have been short projects, lasting about a week and a half. The students still received high quality, engaging instruction using scientific best practices, but the culminating projects were less intense. Finally, it is beneficial to make the project cross-curricular. This helps ease the time constraints. While it may seem intimidating to plan and implement a PBL in science, it can be quite fun, and students become better problem solvers and critical thinkers through this engaging form of instruction.

Advice for Administrators

Successful implementation of Problem-Based Learning units in science takes careful planning, professional development, and support from district and school level administrators. Administrators should be prepared to support a dynamic classroom environment, provide flexibility for pacing and cross-curricular connections, and allow teachers time to review, reflect, and revise their units.

School administrators may find it shocking to walk into a classroom during a PBL unit. It will not look normal. Classes are often messy, full of movement, and loud in volume as students use communication and collaboration skills to solve problems. This dynamic learning environment is unlike many traditional classrooms, and adjustment to this may take time.
Administrators will also need to understand that Problem-Based Learning is best suited for combining related learning objectives into a cohesive unit of study. Sometimes these learning objectives are cross-curricular or are from multiple units of study throughout the course. Researchers recommend that PBL units be designed to "embody a multitude of science" standards [6]. Careful consideration should be given to provide teachers flexibility with course pacing to ensure standards can be grouped together as needed. If strict pacing is expected, teachers will struggle to identify enough related standards to make it worth taking the time to complete the investigation.

In-depth projects take students on a journey to discover the content of the course themselves, but careful planning must be done to guide them to learn the significant content and not veer too far off course. Administrators can help teachers through this process, by providing them time to refine their big questions, identify intended learning objectives, reflect, and revise their unit. Introducing teachers to a set procedure for revision and reflection, and providing them time to complete it, is an integral component to the success of Problem-Based Learning.

Conclusion

Problem-Based Learning has the potential to produce significant positive outcomes for students. Increased student engagement and opportunities for in-depth critical thinking are natural products of the PBL process. Teachers find PBL challenging because it does take additional time for planning and material acquisition, but experience has shown that the benefits outweigh these challenges. Setting clear goals, identifying specific learning objectives, and developing big questions that tie these together help increase the success of the unit. Additionally, administrators can help teachers succeed in implementing a Problem-Based Learning unit by understanding the dynamic nature of the PBL environment, providing flexibility with unit pacing, and setting aside time for refining, reflection, and revision of the unit.

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