NEW VISTAs IN SCIENCE EDUCATION

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Abstract

In the summer of 2012, a colleague and I attended the four-week Virginia Initiative for Science Teaching and Achievement (VISTA) Elementary Summer Science Institute where we were trained to conduct inquiry-based science teaching in a problem-based learning setting. We then implemented our training in our own academic classrooms by developing a Problem-Based Learning unit meeting the objectives of our Virginia standards-based science curriculum and selecting a topic with ties to our local community. Toward demonstrating that students, teachers, and educational systems stand to benefit from the implementation of this methodology, this article clarifies the following aspects: 1) outlines the problem, scenario, and process of developing a Problem-Based Learning unit; 2) explains the delivery in the classroom; 3) analyzes ongoing formative and summative assessments; 4) and, discusses the influence on students, teachers, and instruction as a whole.

Introduction

In the summer of 2012, my colleague and I had no idea what we were getting into when we applied to attend the Virginia Initiative for Science Teaching and Achievement (VISTA) Elementary Summer Science Institute. We were both relatively new to our grade 4 team, and the opportunity to receive science professional development while being paid was appealing. During Week One of the four-week Institute, we learned how to conduct inquiry-based science teaching in a problem-based learning setting, improve science instruction by developing scientific literacy, and provide a broader view of science for our students, including scientific knowledge, methods of science, and the Nature of Science. In Weeks Two and Three, we taught inquiry-based science collaboratively with other area elementary teachers to high-needs students in a summer science camp. Our theme was space exploration. Week Four brought the real test: how do we take what we learned over the summer and implement inquiry-based science instruction in our own academic classrooms in Middlesex County, Virginia?

The Problem, the Proposal, and the Process

Middlesex County is a rural area nestled among several waterways boasting 135 miles of linear shoreline along the Rappahannock River, the Piankatank River, Stingray Point, and the Chesapeake Bay. So, when tasked with developing a Problem-Based Learning unit to deliver to
our students, it was only natural that we chose one that not only met the objectives of our curriculum, but also was indigenous to our area. We read in the local newspapers that, at the time of our Summer Institute, some of our area waterways had been closed to shellfish harvesting. The amount of harvestable water acreage had decreased from 100,000 to 50,000 acres. With so many watermen and women in our area and others with ties to the local waterways, we chose natural resources and watersheds as the theme for our unit.

The Virginia Initiative for Science Teaching and Achievement (VISTA) defines Problem-Based Learning (PBL) as students solving a problem with multiple solutions over time like a scientist in a real-world context. The first step in writing our PBL unit was to establish the overarching question or problem. It had to be a real scientific problem with multiple solutions stated as a question to be solved over time. Since our unit of study was natural resources and watersheds, we chose the question, “How can we improve the health of our local waterways?” Problem-Based Learning provides authentic problem solving and hands-on, self-directed learning with the teacher serving the role of coach. According to Gallagher, “Fundamental to PBL is the ill-structured problem that drives the learning experience” [1]. Gallagher goes on to define an ill-structured question as one where elements of the problem are unclear or missing. It can change with additional information. It is authentic in that it is modeled on circumstances in the real world. It is flexible and sometimes ambiguous as it offers multiple possible solutions and, like real-world problems, it permeates many disciplines [1]. A PBL unit is designed around a core curriculum, in our case VISTA’s Nature of Science (see Figure 1) and Virginia’s Standards of Learning (SOL) (see Table 1), and addresses specific content learning goals [2]. Because of its “fuzzy” or ill-defined structure, however, teachers may initially feel apprehensive, especially as the teacher’s role changes to that of a facilitator or coach and students direct their own learning; but as teachers see students employing higher-level thinking skills and cognitive sophistication, their apprehensions are assuaged. Although Problem-Based Learning involves an ill-structured question, it actually requires quite a lot of planning.

Secondly, we developed our question map using the Virginia’s Science Standards of Learning, pens, a pad of sticky notes, and a wall of sheet glass windows [3]. We had to anticipate where students would go with their thinking, what resources and background knowledge they would need, what problems or misconceptions they might have, and how we would assess their progress along the way. After hours of rearranging and replacing questions on sticky notes
placed on window panes, we created the question map and the proposal (see Figure 2 and Table 2) and transferred our thoughts from glass to paper to computer, and on to the classroom.

NATURE OF SCIENCE (NOS)

*Science demands evidence
*Science uses a blend of logic and imagination
*Scientific ideas are durable yet subject to change
*Science is a social activity
*Scientists attempt to avoid bias
*Scientific knowledge is the product of observation and inference
*Scientific laws and theories are different kinds of scientific knowledge
*Scientists use many methods to develop scientific knowledge

Figure 1. Nature of Science from the Virginia Initiative for Science Teaching and Achievement (VISTA).

<table>
<thead>
<tr>
<th>Subject</th>
<th>Grade Level</th>
<th>Standard</th>
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<tbody>
<tr>
<td>Science 2010</td>
<td>3</td>
<td>3.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) observations are made and are repeated to ensure accuracy; b) predictions are formulated using a variety of sources of information; c) objects with similar characteristics or properties are classified into at least two sets and two subsets; d) natural events are sequenced chronologically; e) length, volume, mass, and temperature are estimated and measured in metric and standard English units using proper tools and techniques; f) time is measured to the nearest minute using proper tools and techniques; g) questions are developed to formulate hypotheses; h) data are gathered, charted, graphed, and analyzed; i) unexpected or unusual quantitative data are recognized; j) inferences are made and conclusions are drawn; k) data are communicated; l) models are designed and built; and, m) current applications are used to reinforce science concepts.</td>
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3.4 The student will investigate and understand that adaptations allow animals to satisfy life needs and respond to the environment. Key concepts include a) behavioral adaptations; and, b) physical adaptations.
3.5 The student will investigate and understand relationships among organisms in aquatic and terrestrial food chains. Key concepts include
   a) producer, consumer, decomposer;
   b) herbivore, carnivore, omnivore; and,
   c) predator and prey.

3.6 The student will investigate and understand that ecosystems support a diversity of plants and animals that share limited resources. Key concepts include
   a) aquatic ecosystems;
   b) terrestrial ecosystems;
   c) populations and communities; and,
   d) the human role in conserving limited resources.

3.8 The student will investigate and understand basic patterns and cycles occurring in nature. Key concepts include
   a) patterns of natural events such as day and night, seasonal changes, simple phases of the moon, and tides;
   b) animal life cycles; and,
   c) plant life cycles.

3.9 The student will investigate and understand the water cycle and its relationship to life on Earth. Key concepts include
   a) there are many sources of water on Earth;
   b) the energy from the sun drives the water cycle;
   c) the water cycle involves several processes;
   d) water is essential for living things; and,
   e) water on Earth is limited and needs to be conserved.

3.10 The student will investigate and understand that natural events and human influences can affect the survival of species. Key concepts include
   a) the interdependency of plants and animals;
   b) the effects of human activity on the quality of air, water, and habitat;
   c) the effects of fire, flood, disease, and erosion on organisms; and,
   d) conservation and resource renewal.

3.11 The student will investigate and understand different sources of energy. Key concepts include
   a) energy from the sun;
   b) sources of renewable energy; and,
   c) sources of nonrenewable energy.

4 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
   a) distinctions are made among observations, conclusions, inferences, and predictions;
   b) objects or events are classified and arranged according to characteristics or properties;
   c) appropriate instruments are selected and used to measure length, mass, volume, and temperature in metric units;
   d) appropriate instruments are selected and used to measure elapsed time;
   e) predictions and inferences are made, and conclusions are
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4.4 The student will investigate and understand basic plant anatomy and life processes. Key concepts include
   a) the structures of typical plants and the function of each structure;
   b) processes and structures involved with plant reproduction;
   c) photosynthesis; and,
   d) adaptations allow plants to satisfy life needs and respond to the environment.

4.5 The student will investigate and understand how plants and animals, including humans, in an ecosystem interact with one another and with the non-living components in the ecosystem. Key concepts include
   a) plant and animal adaptations;
   b) organization of populations, communities, and ecosystems and how they interrelate;
   c) flow of energy through food webs;
   d) habitats and niches;
   e) changes in an organism’s niche at various stages in its life cycle; and,
   f) influences of human activity on ecosystems.

4.9 The student will investigate and understand important Virginia natural resources. Key concepts include
   a) watersheds and water resources;
   b) animals and plants;
   c) minerals, rocks, ores, and energy sources; and,
   d) forests, soil, and land.

5.6 The student will investigate and understand characteristics of the ocean environment. Key concepts include
   a) geological characteristics;
   b) physical characteristics; and,
   c) ecological characteristics.

5.7 The student will investigate and understand how Earth’s surface is constantly changing. Key concepts include
   f) weathering, erosion, and deposition; and,
   g) human impact.
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<table>
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<tr>
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<tbody>
<tr>
<td><strong>6.1</strong></td>
<td>The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which&lt;br&gt;  a) observations are made involving fine discrimination between similar objects and organisms;&lt;br&gt;  b) precise and approximate measurements are recorded;&lt;br&gt;  c) scale models are used to estimate distance, volume, and quantity;&lt;br&gt;  d) hypotheses are stated in ways that identify the independent and dependent variables;&lt;br&gt;  e) a method is devised to test the validity of predictions and inferences;&lt;br&gt;  f) one variable is manipulated over time, using many repeated trials;&lt;br&gt;  g) data are collected, recorded, analyzed, and reported using metric measurements and tools;&lt;br&gt;  h) data are analyzed and communicated through graphical representation;&lt;br&gt;  i) models and simulations are designed and used to illustrate and explain phenomena and systems; and current applications are used to reinforce science concepts.</td>
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<td><strong>6.7</strong></td>
<td>The student will investigate and understand the natural processes and human interactions that affect watershed systems. Key concepts include&lt;br&gt;  a) the health of ecosystems and the abiotic factors of a watershed;&lt;br&gt;  b) the location and structure of Virginia’s regional watershed systems;&lt;br&gt;  c) divides, tributaries, river systems, and river and stream processes;&lt;br&gt;  d) wetlands;&lt;br&gt;  e) estuaries;&lt;br&gt;  f) major conservation, health, and safety issues associated with watersheds; and,&lt;br&gt;  g) water monitoring and analysis using field equipment including hand-held technology.</td>
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<td><strong>6.9</strong></td>
<td>The student will investigate and understand public policy decisions relating to the environment. Key concepts include&lt;br&gt;  a) management of renewable resources;&lt;br&gt;  b) management of non-renewable resources;&lt;br&gt;  c) the mitigation of land-use and environmental hazards through preventive measures; and,&lt;br&gt;  d) cost/benefit tradeoffs in conservation policies.</td>
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<tr>
<td><strong>VA Studies 2008</strong></td>
<td><strong>4</strong></td>
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<tr>
<td><strong>VS 2</strong></td>
<td>The student will demonstrate knowledge of the physical geography and native peoples, past and present, of Virginia by&lt;br&gt;  a) locating and describing Virginia’s Coastal Plain (Tidewater), Piedmont, Blue Ridge Mountains, Valley and Ridge, and Appalachian Plateau.</td>
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<tr>
<td><strong>VS 2</strong></td>
<td>The student will demonstrate knowledge of the physical geography and native peoples, past and present, of Virginia by&lt;br&gt;  b) locating and identifying water features important to the early history of Virginia (Atlantic Ocean, Chesapeake Bay, James River, York River,</td>
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</tbody>
</table>
How do the local waterways make up the Chesapeake Bay Watershed?

What are the characteristics of the Rappahannock and Piankatank Rivers and their tributaries?

What is nitrogen, turbidity, salinity, and dissolved oxygen and how do we test for them?

- Make a model of a watershed
- Soak it up/journey of a Raindrop

What marine life exists in our bay area?

How do plants and animals interact with one another in our local aquatic ecosystem?

What are the negative influences of human activity on local waters?

How does pollution affect the quality of water in the rivers and the bay?

Why has the shellfish population declined?

What is run-off?

- Water Testing
- Soil Sampling
- Oil Spill Clean-up

What are some ways we can conserve our local aquatic resources?

What can we do to increase the quality of our local waters?

What can we do to increase the local shellfish populations?

- Make a reef ball
- Plant sea grasses
- Turbidity and oyster experiment

Figure 2. Question Map from the VISTA template.
<table>
<thead>
<tr>
<th><strong>Theme</strong></th>
<th>Natural Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Problem</strong></td>
<td>How can we improve the health of the local waters?</td>
</tr>
<tr>
<td><strong>Student Roles</strong></td>
<td>C.R.A.B.S.—Conservation, Research and Bay Scientists</td>
</tr>
<tr>
<td><strong>Scenario</strong></td>
<td>Science Investigators for the Virginia Department of Health.</td>
</tr>
<tr>
<td><strong>Resources</strong></td>
<td>Area waters in Gloucester, Matthews, and Middlesex have been closed to shellfish harvesting. The amount of harvestable water acreage has decreased from 100,000 to 50,000 acres in the past 12 months. The Virginia Department of Health has commissioned you as science investigators—CRABS—to help the local watermen regain and restore their fishing grounds.</td>
</tr>
<tr>
<td><strong>Culminating Project/Assessment</strong></td>
<td>Presentation of investigations at Urbanna Oyster Education Day.</td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td>Water testing, proper instruction on cutting tools for watershed</td>
</tr>
</tbody>
</table>
might arise as students gather information) and reef construction.

The Delivery

The delivery came next. Students were informed of a threat that was facing their community. Area waters in Gloucester, Mathews, and Middlesex have been condemned from shellfish harvesting. The amount of harvestable water acreage had decreased from 100,000 to 50,000 acres in the past twelve months. The Virginia Department of Health commissioned them as science investigators—Chesapeake Research and Bay Specialists (C.R.A.B.S.)—to help the local watermen regain and restore their fishing grounds. Since some of the waters had been condemned, students had to determine how they could improve the health of the local waterways. Students were introduced to VISTA’s definitions of the Nature of Science, and told that they would assume the role of real scientists using the tenets of the discipline to tackle this real-world issue in their community.

Many students have family members who are watermen and women who make their living from the water; others live on or near the local waterways, have enjoyed water activities, such as boating, fishing, etc., and were concerned about the impact of this issue on their community and their lives. Students living or traveling near the waterways began to form hypotheses for why the waterways had been condemned. Several students mentioned concern over bridge construction near the Piankatank River. The Piankatank was one of the waterways recently closed to shellfish harvesting. Could human impact be the cause of condemned waters? One student whose father is an oyster farmer was concerned that the lack of oysters was negatively affecting the waters. Students contemplated the relationship between the oyster population and the health of the waterways.
waterways. They began to form questions. There are many waterways in the area. Are all waterways equally impacted? Are some healthier than others? How can they test the health of the waterways? Beaton and I had anticipated many of their questions on our question map, but the students raised some questions that we didn’t consider. We weren’t aware of the bridge construction when we were developing the lesson. We needed to include these new questions as students began their investigations.

Using key concepts from the Virginia Grades 3-6 Science Standards of Learning and the Nature of Science, students began to research and understand the interdependency of plants and animals in an aquatic environment. They learned that a food web shows the complex relationships between plants and animals, and how energy flows from producers to consumers to decomposers and back to producers. Bay food webs extend out of the water because land animals and humans eat from the Bay. The Nature of Science states that scientists use many methods to develop scientific knowledge, so students not only researched and investigated, but they also created models of a watershed to better understand their own local watershed, its tributaries, water resources, and characteristics. Students continued their investigations by conducting water and soil testing on samples from three local waterways: the Rappahannock River, the Piankatank River, and the Urbanna Creek.

Again, using Virginia’s Science Standards of Learning, students studied runoff and contemplated human impact on the watershed. In the surrounding rural area, there are businesses, many farms (both animal and crop producing), wooded areas, and residences. Students noted a large paper mill on a nearby tributary. Are fertilizers and animal waste affecting the health of the local waterways? Another student mentioned a water treatment plant near her home on the Urbanna Creek. Several students referred again to the bridge construction on the Piankatank. What is the impact of the ongoing projects and businesses located directly on the waterways? Are there better practices that businesses and people in the community can employ to help improve the health of the local waterways? Science is a social activity. As students wrestled with questions and issues and then conducted investigations, they worked together cooperatively offering new insights and providing checks and balances.

One of the strengths of the VISTA program is that teachers receive ongoing support throughout the academic year as they return to their respective schools to implement their
Problem-Based Learning unit and the VISTA teaching methods into their science instruction. Our coach, Sara Beam, proved to be an invaluable resource both for her support and knowledge in our content area. Our coach is a teacher at the Chesapeake Bay Governor’s School for Mathematics and Marine Science, and taught students how oyster farming can help clean area waters. We also partnered with VIMS (The College of William & Mary’s Virginia Institute of Marine Science) to learn how to grow sea grasses and how the use of reef balls can encourage the growth of oyster populations. Students incorporated the engineering process as they researched, designed, and made their own reef ball models out of clay.

Through the process of the Problem-Based Learning unit, students learned that some of the area waters had increased algal bloom, most likely from runoff, which had adverse effects on the health of the water. They suggested that this was one of the reasons for the condemned waters, and better conservation practices would help keep contaminants and pollutants out of the water.

Assessments were ongoing throughout the Problem-Based Learning unit. Formative assessments, such as discussion circles, classroom discussions, journal writings, investigation sheets, design briefs, and teacher observations provided constant feedback and learning checks. Models, diagrams, investigations, and oral presentations were scored according to rubrics, and used as summative assessments. Unit tests, benchmarks, and Standards of Learning tests were also used to assess student progress.

We concluded our unit with an exhibition. Each year in Middlesex County, the town of Urbanna holds the Oyster...
Festival. Part of the weeklong celebration includes the Oyster Education Day which, in cooperation with the Virginia Marine Legacy Program, provides educational opportunities for schools. As their culminating project, fourth grade students from Middlesex Elementary School manned a booth and shared the findings from their Problem-Based Learning unit with other students from area schools. They explained aquatic food webs, conducted water testing, and demonstrated with models the effect of runoff in a watershed.

The Results

The first group of C.R.A.B.S. to participate in this PBL unit began as fourth graders and have just completed fifth grade. Although the sample size was small and select, and this first group of C.R.A.B.S. received subsequent science instruction from teachers who did not receive training from VISTA, it is interesting to note that this group had a 100% pass rate on the Grade 5 science SOL, with 78% receiving scores of Pass/Advanced and 33% receiving perfect scores, while the grade level as a whole had a pass rate of 82% with a Pass/Advanced rate of 23%. While initial results were positive, there is still little quantitative, longitudinal data yet available to comprehensively assess students’ progress. Qualitatively, the next grade-level teachers receiving C.R.A.B.S. noted high science interest levels, as well as quicker concept attainment and retention in those students who participated in the Problem-Based Learning unit. Students participating in the problem-solving unit were highly engaged and enthusiastic toward learning science. In Ericson’s book, Concept-Based Curriculum and Instruction, Caine & Caine and Perkins suggest that “if knowledge is going to be retained and understood, then students must use it in a demonstration or complex performance” [4]. The VISTA method places students at the center of hands-on, inquiry-based learning. Additionally, students are introduced to science in an authentic, real-world application operating as a professional in the field. They become well versed in the Nature of Science and are able to transfer concepts to other areas of science. They view science through the lens of a scientist.

According to Gallagher, the power of Problem-Based Learning units, such as the one described above, “is not solely in its power to deliver content but also because it delivers content in a way that opens the door to other cognitive and affective outcomes” [1]. Employing teaching and learning methods as demonstrated and exacted in the VISTA model teaches students to think conceptually and critically. Ericson suggests that to develop the thinking abilities of students systematically, educators need to develop an idea-centered model of curriculum design. Idea-centered curricula focus on deeper, conceptual ideas and use facts to support the understanding.
The Nature of Science states that science demands evidence and as such, teaches students that facts are not only critical for building content knowledge, “but are also tools for gaining insight into conceptual ideas that transfer across time and culture” [4]. The VISTA method trains teachers how to emphasize key concepts and principles, and build deeper understanding, rather than just covering a myriad of topics and facts to be learned. The Nature of Science also tells us that scientific principles are durable yet subject to change. Principles are enduring, but should be viewed in context and may be refined with new knowledge and discoveries:

Principles are key conceptual relationships that are always true and have significant roles in a discipline. They stand the test of eternal time, they will never change, and they are the cornerstones for understanding and applying the knowledge of a discipline [4].

Science is a blend of both logic and imagination. The Virginia Initiative for Science Teaching and Achievement (VISTA) encourages students and teachers to employ both while exploring new vistas. The National Research Council recognizes the National Science Education Standards as the most comprehensive and sound treatment of a discipline from the conceptual design perspective, and consequently provides an excellent model for writing essential conceptual understanding in other content-based disciplines [4]. The VISTA training has been transformative in our science teaching and beyond. It has given us the tools and the confidence to provide engaging, high-quality science instruction to our students. Moreover, this method of teaching is applicable to more than just science, and helps develop not just good science teachers, but good teachers overall.

References


