PROJECT REPORT

Full Immersion: The Chesapeake Bay Watershed as an Environment for Learning Science in a Civic Context

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The Bay as a Rich Context for Learning

The Chesapeake Bay, North America's largest estuary system, is a case study in the connections between science and civic engagement, the power of science to provide key insights into challenging issues, and the limitations of science to effect change in contested civic spheres. The Bay's watershed, which encompasses more than 64,000 square miles and parts of six states in the Eastern U.S., is home to more than seventeen million people whose activities within the watershed affect the quality of water in the Bay and therefore the biota that live there (Lippson and Lippson 2006). Waste water treatment, storm water runoff, confined animal production facilities, energy extraction and use (e.g., gas fracking and coal-fired power plants), and countless other influences have earned the Bay a grade of D for overall health (thirty-one of 100 for Bay Health Index; CBF 2010). These pollutants cause environmental changes such as oxygen-deficient dead zones, sedimentation, and exposure to endocrine disruptors that in turn affect Bay fauna such as blue crabs (*Callinectes sapidus*), Eastern oysters (*Crassostrea virginica*), and game fish species. These species are integral to the Bay's health, and therefore declines in their populations affect not only the ecosystem but also the local economy (CBF 2012).

The watershed is a stage set with complex and controversial civic issues in which a diverse ensemble of actors has roles: watermen, farmers, industrialists, local officials, recreational users and tourists, state- and regional-level leaders, and the millions of other citizens who live in the watershed. These issues and their interrelated influences are rich in scientific content: water chemistry, biogeochemical cycles, global climate change,

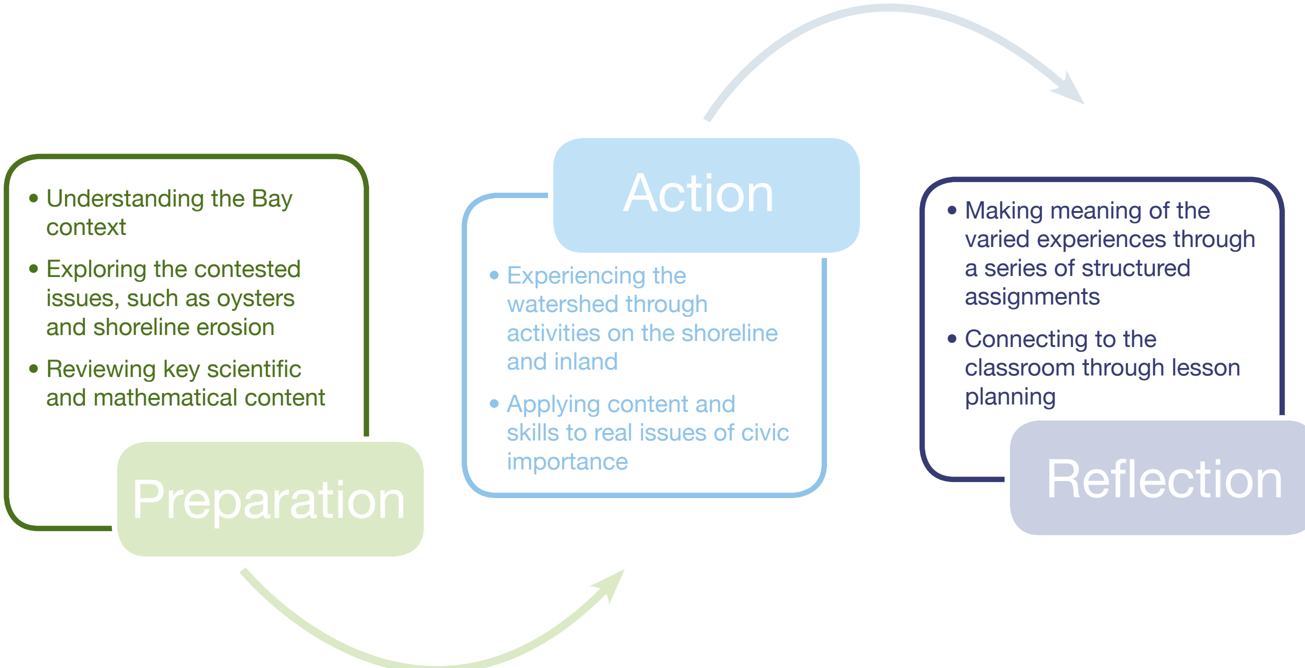


FIGURE 1. Overview of a national model for environmental education, "Meaningful Watershed Educational Experiences."

population dynamics, etc. Leaders in the environmental sciences argue that these issues require urgent action: "Nothing could be more short-sighted than apathy, lax enforcement, or fear mongering. The time for action and stewardship is now" (CBF 2010). In response to similar calls over time, including the multi-state *Chesapeake 2000* agreement (CBP 2000), environmental educators have sought to effect change in the Bay's watershed by better preparing teachers to engage their K-12 students in Meaningful Watershed Educational Experiences (MWEEs; CBPEW 2001). Three-phase MWEEs (Fig. 1) are place-based activities designed to not only foster understanding of the Bay and a sense of connection to it but also to provide an impetus to take action on its behalf. In Virginia, Chesapeake Bay Academies serve as a venue for professional development for K-12 teachers seeking to learn about the Bay and develop MWEEs for their own classrooms. Each year the Virginia Resource Use and Education Council (VRUEC) sponsors approximately six Academies and provides financial support for them through subawards of National Oceanic and Atmospheric Administration funding.

In hosting our first Bay Academy at Longwood University in 2011, we expanded the reach of our long-term Science Education for New Civic Engagements and Responsibilities (SENCER) project to include in-service teachers.[1] Our Bay Academy, which we called Summer of Learning: Science Teachers Investigating the Chesapeake Environment (SOLstice), also marked an expansion of the Academies' reach by including pre-service teachers in addition to its traditional in-service teacher population. Our key goals in developing SOLstice were to use a SENCER approach to structure a unique learning experience for pre- and in-service K-12 science teachers. Focused on authentic interdisciplinary investigations of the Chesapeake Bay watershed, SOLstice facilitated the exploration of scientific and mathematical content, the connec-

1 Since 2002, Longwood has been actively involved in SENCER, and our Bay Academy builds on previously successful SENCER courses taught at LU including The Power of Water (POW), which is part of the SENCER Model Series (Fink and Parry 2007). In both 2008 and 2010, POW was linked with a statistics course for non-science majors through a semester-long research project (Fink and Lunsford 2009 and Lunsford and Fink 2010).

tions among and between science content and social and civic issues, and the infusion of these linkages into the teachers' own work with their students.

Project summary

Course structure

SOLstice was developed by a team of Longwood faculty with expertise in mathematics, science, and science education and was implemented as a four-credit summer course open to pre-service teachers for undergraduate credit and in-service middle-school teachers for graduate credit. Ten SOLstice participants, two middle-school science teachers and eight pre-service teachers, completed a series of explorations focused on "interaction between natural and social systems" (CBF 2004). In addition to honing their data-collection and analysis skills, the participants made critical linkages between the material they were learning and the middle-school science and mathematics curricula (i.e., the Virginia Standards of Learning or SOLs; VA DOE 2003 and 2009). The meta-structure of the project was a multi-week MWEE experience:

Preparation phase: The first week of the course, which participants completed through online instruction, focused on developing an understanding of the Chesapeake Bay context and on building foundational knowledge of basic statistics, chemistry, physics, and environmental science that would be applied in the action and reflection phases of the course.

Action phase: Participants completed the second week of the course in true Chesapeake Bay country at Longwood's Hull Springs Farm, a 600+-acre coastal property located on the Northern Neck of Virginia. This intense week included a series of smaller, more focused MWEE activities such as biodiversity sampling at a "living shoreline" demonstration site. Participants then moved inland to complete the third week on the Longwood University campus, still in the watershed but well out of sight of the Bay. In this third week, scientific investigations and discussions continued both in the field and in a more traditional classroom/laboratory environment with an emphasis on connecting knowledge gained to the context of teachers' own classrooms.

Reflection, analysis, and reporting phase: In the final week of the course, participants devoted energies to the completion of lesson planning activities and a course portfolio. This closing week allowed participants to reflect on all of the SOLstice activities, including the series of smaller MWEEs that also included reflection and analysis components.

Specific contexts for civic engagement and scientific inquiry

SOLstice participants explored many aspects of the Bay ecosystem, but here we highlight two specific issues to demonstrate the interdisciplinary inquiry into challenging, unresolved questions that characterized the project.

Is the menhaden fishery sustainable? SOLstice participants were challenged to seriously consider the fishing of Atlantic menhaden (*Brevoortia tyrannus*), which is argued to be one of the "most important fish in the sea" (Franklin 2007; Fig. 2A). After a Place-as-Text exploration[2] (Braid and Long 2000) in the community to learn about citizens' perspectives, participants toured Omega Protein, Inc., the largest fishmeal processing plant in the U.S. and a major employer in the area. There they heard the industry's perspective on the importance of menhaden and sustainable fishing practices. Participants then heard a different viewpoint from a Chesapeake Bay Foundation fisheries biologist and learned about menhaden populations and environmental consequences of their harvest. In an interactive session about the importance of civic engagement led by a representative from the Virginia Department of Environmental Quality, participants created a plan to address the complications of identifying stakeholders, involving the community, and building consensus for environmental policy. As a final step in this exploration, participants modeled fish populations using activities suitable for the K-12 classroom (modified from PBS 2011a and 2011b) and plotted growth and decay curves.

2 SOLstice participants engaged in a City-as-Text "walkabout," part of the Place-as-Text pedagogy described by Braid and Long (2000). For the activity, which is preceded by assigned context readings, the explorers gather at a central location to which they will return after their journeys are complete. The larger group is divided into smaller working groups that then set out with the goal to deconstruct an "uncharted territory." Groups have a clear objective: to use observational skills, pick up newspapers and other artifacts, and engage in conversation with local people in order to gain a deeper understanding of an overarching theme (e.g., the health of the Chesapeake Bay). Once the working groups return to the central location, they discuss their notes in the larger group, comparing and contrasting their experiences and developing an understanding of the text of the place they have just "read."

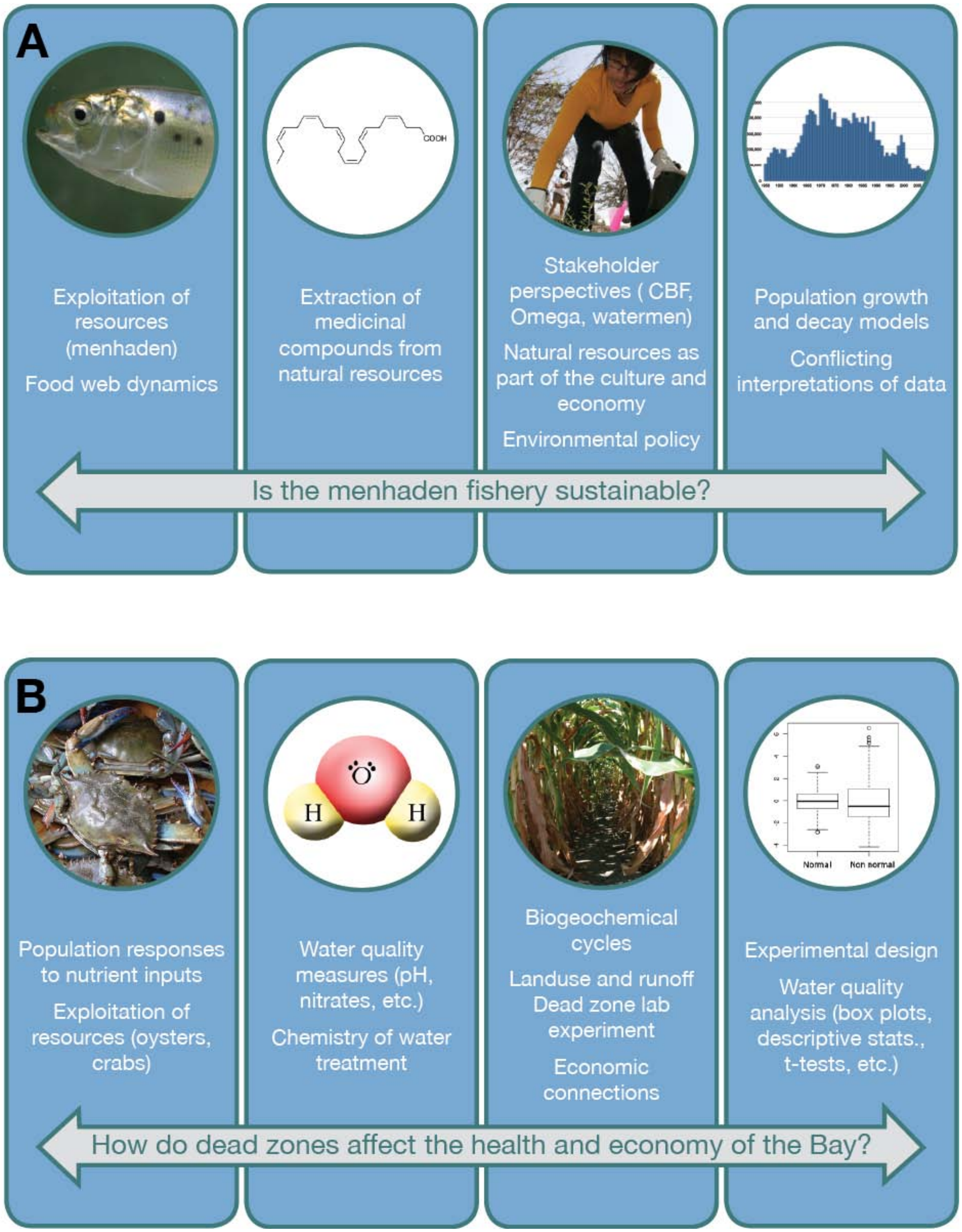


FIGURE 2. Summary of the multidisciplinary exploration of the science content and civic issues related to menhaden fishing (A) and dead zones (B) in the Chesapeake Bay.

How do dead zones affect the health and economy of the Bay? SOLstice participants also were challenged to seriously consider complex ecosystem dynamics in the context of dead zones in the Bay (Fig. 2B). At Hull Springs Farm, participants performed a battery of water-quality tests (e.g., pH, nutrient levels, dissolved oxygen, salinity, etc.) and conducted an experiment to assess the effects of nutrients on algae growth. In addition to numerical summaries of the water-quality data, participants used box plots to compare test results from two locations and to consider the inherent variation in measurements. A full-day excursion on board an historic sailing oyster boat, a skipjack, afforded participants new perspectives on the effects of nutrient pollution on oyster and crab populations, the importance of those animals in regional history and contemporary culture, and their role in the natural systems of the Bay. After a second Place-as-Text exploration in Farmville, Virginia, to learn about perspectives on the health of the Bay from citizens who live in the watershed but not near the Bay, participants toured two municipal facilities: the drinking water filtration plant and the waste water treatment plant. At both locations, participants heard from the public officials who serve as stewards of the local water resources and learned of the complex chemical and biological processes involved in treating water within the Bay's watershed.

Assessment tools

To evaluate this first iteration of SOLstice, we asked course participants to complete a suite of assessment instruments: (1) an internally developed pre- and post-course content knowledge assessment focused on key Bay issues and basic chemistry, physics, statistics, geography, and environmental science; (2) a tailored pre- and post-course version of the Student Assessment of Their Learning Gains (SALG 2011) focused on participant attitudes about science, civic engagement, and other aspects of the SOLstice experience; and (3) a post-course Chesapeake Bay Academy Evaluation (provided by VRUEC; unpublished) focused on more traditional "course evaluation" topics. SOLstice also was documented by Longwood University's Information and Instructional Technologies Services, and the resulting video is available online (http://youtu.be/gAtLWXohULI).

Project outcomes

Although the sample size for the SOLstice pilot was small (i.e., ten participants), our assessment efforts provided some interesting insights. For example, based on the pre- and post-course content assessments, we noted that SOLstice participants had incoming fundamental knowledge of statistics including the ability to recognize explanatory and response variables in an experiment and to read graphical displays of data including box plots and histograms. We did see some improvement in participants' graphical recognition of variability (i.e., standard deviation) of a quantitative variable. The pre- and post-course content knowledge assessment in chemistry focused on formulae of binary ionic compounds, basic valence electron structure, solubility of binary ionic compounds, properties of water, and common units of measure. As with the statistics assessment, we found that participants had some prior chemical knowledge. Although there was no single topic that showed significant improvement, four of the six participants who completed both the pre- and post-course content assessments showed overall improvement in their knowledge of these chemistry topics.

The Bay Academy Evaluation provided important insights into the participants' experiences, particularly related to their interest in the civic issues, and participant comments (below and later in this report) were compiled from responses to that instrument. One participant reported having:

> "a much greater appreciation for the Chesapeake Bay and my environment in general. I didn't really care for ecology much before this program, but now I think about some aspect of it every time I walk outside. I am now inspired to bring that to my future students as well."

Two other participants stated:

> "I am prepared to discuss watersheds in my classroom and stress the idea of reducing, reusing and recycling [to] decrease pollution in the world."

> "I have found my interest in caring for the health of the Bay and have the facts to back up myself when I push people to act in a more Bay-friendly way."

In completing the SALG instrument, participants reported gains in understanding how to think like a scientist; the scientific content of the course, statistics, and MWEEs;

the power of science to affect their lives; and their abilities to persist when working on hard problems.[3] Strong majorities (≥ 70 percent) of participants expressed interest in adding more quantitative components to their teaching, integrating Bay issues into their classrooms, and engaging their own students in linkages between scientific and civic issues. However, we noted the absence of a gain in participants' confidence in their preparation to engage students in the linkages between scientific and civic issues as well as their enthusiasm for integrating more quantitative components into their teaching. Interestingly, participants did not appear to make gains in their habits of applying scientific knowledge and reasoning to civic actions outside the classroom.

Reflections

A primary goal of SOLstice was to provide unique learning experiences for pre- and in-service teachers, experiences focused on authentic investigations that drew on knowledge and skills from multiple disciplines. Assessment results clearly show that this goal was achieved:

> "I loved the field experiences and being able to work in the water. Getting my hands wet and testing the water was very valuable."

> "... getting out in the field and learning about the Bay made the concepts more relevant and real. Seeing perspectives from several different views, such as the menhaden issue, helped to gain a broader sense of the problem and the difficulties in resolving it."

Furthermore, we sought to facilitate the transfer of content and skills from the university environment to the K-12 classroom, and we believe this was a successful component of the project overall. The collaboration between the pre- and in-service teachers provided a unique opportunity for discussion of instructional strategies, one that participants clearly appreciated: "I also thought it was valuable to have both practicing and pre-service teachers involved in the program because we were able to learn a lot from each other." By participating in activities designed to strengthen lesson-planning skills, participants believed they could better incorporate the Bay and its complex issues into their science lessons within the framework of the Virginia SOLs for science and mathematics:

> "The most valuable aspect was that we were able to work in the field and bring it back to the classroom and discuss how we could use it in our own classroom."

> "I feel more confident designing a project that looks at the complete picture of the watershed. As a teacher of inland students, it can be more challenging to convince them of their connection. This program gave me resources and ideas to implement lesson plans that would allow the students to see the possible effects of their actions."

> "[I] am more confident in my skills in using math in the classroom and leading authentic MWEE activities for my students."

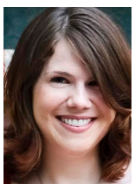
However, due to the fact that this was the first iteration of the course and course assignments had not been field tested, the richness of the MWEE construct was not fully realized in all of the participants' lesson plans. While many lesson plans contained MWEE components such as hands-on, student-centered outdoor explorations, only one of the submitted lesson plans provided for sustained student action stemming from their experience in the watershed. In future iterations of the course, the lesson planning assignment requirements will be modified to explicitly highlight ongoing scientific exploration as a key MWEE component.

Another emphasis of the course was the integration of scientific knowledge and civic engagement to result in action. Even though we studied the science within the context of the Bay, SALG data indicated that there were not strong majorities of participants saying they were in the habit of taking public action related to scientifically oriented civic issues or even discussing science-related issues informally with friends or family. This lack of integration could be a function

3 In addition to questions on the standard SALG instrument, we also included specific questions for the SOLstice experience such as: Presently I understand (1) mathematical formulas and statistics I find in textbooks, websites, magazines and newspapers, and other media and (2) graphs and descriptive statistics for a quantitative variable (i.e., histograms, boxplots, measures of center and spread). Presently I am (1) enthusiastic about using statistics in my teaching; (2) interested in adding a more quantitative component to the teaching of my classes; (3) confident that I understand statistics well enough to use them in my teaching; (4) confident in my understanding of MWEEs; (5) interested in integrating Chesapeake Bay issues into my classroom experience; and (6) confident in my understanding of Chesapeake Bay issues.

of SOLstice's short duration, but it also may indicate some room for improvement of the "action phase" of the course. We continue to consider ways in which this key SENCER component can be strengthened, and a first step will be a focus on the "action phase" in the lesson plan assignment.

Overall, we were successful in applying the SENCER approach to our SOLstice project to provide a unique learning experience for participants as well as the faculty involved. We believe that the interdisciplinary science curriculum framed around key civic issues modeled a new approach for a classroom environment for middle-school educators. Furthermore, the opportunity for collaboration between pre- and in-service teachers provided professional enrichment and growth for both groups.



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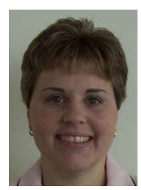

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