2017

Future Water Stewardship and Fact-Based Water Policy: An Aquatic Science Education Pathway Model

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ABSTRACT

Texas Aquatic Science originated from a project seeking better ways to educate students about water because of concern that current education was failing to promote good decisions about water by adult citizens and political leaders. A comprehensive water education curriculum was developed to engage learners from middle school through university using an education pathway to create water-savvy citizens of tomorrow who will take personal action to ensure effective stewardship of water and support evidence-based water policies. This paper will describe the pathway and present results of research on the pathway's effectiveness with middle and high school students and teachers.

INTRODUCTION

In May 2010 the Headwaters to Ocean Project began as a partnership between the Meadows Center for Water and the Environment at Texas State University and the Harte Research Institute for Gulf of Mexico Studies at Texas A&M University-Corpus Christi. The project objective was to devise novel experiential, technology-enhanced ways to improve water education for students and teachers. The initial funder was seeking to support better ways to educate students about water, because of concern that current education was failing to promote good decisions about water by adult citizens and political leaders. Elected and government agency leaders are commonly blamed for water pollution events or when water supplies become overused.

The immediate goal of this project was to develop various water-related education programs and technology applications that would profoundly change how youth engage with and relate to water. The long-term goal was to help create adults of tomorrow who would understand and advocate effective stewardship of water and support evidence-based water policies.

Studies confirm a crisis in education about water in the U.S., the significance of which is only multiplied as drought and flood conditions worsen across regions of the country. Mapping the Future Project, which was supported by the National Institute of Food and Agriculture, found that educational systems have not effectively educated students about the importance of water (Kushner, 2010). Even though water science concepts are generally included in most science education curricula (Ben-Zvi-Assaraf and Orion, 2005), work indicates that an understanding about water is low among students (Covitt et al., 2009; Dickerson et al., 2007; Ewing and Mills, 1994; Shepardson et al., 2007). Exacerbating inadequate education is that many teachers say they are lacking in their own knowledge about water and how to best provide water education in the classroom (Brody, 1995; Coyle, 2005; Sansom, 2013).

Recent work now points to environmental place-based and experiential education, allowing hands-on experiences in locations familiar to students, as a means of helping students achieve standard academic benchmarks and making connections with the environment (Texas Parks and Wildlife Department, 2010; Rosen, 2012a; Children and Nature Network, n.d.). Significant increases in student understanding of the importance of water and teacher interest in instruction about water were found by Sansom (2013) after teachers had experienced an informal outdoor education program about water. Sansom's results also showed that place-based water education is enhanced by interactive technology, having students directly contact water by using a water "testing" activity, and by linking the outdoor water experience to other water locations generally familiar to the students.

Initial work of the Headwaters to Ocean Project focused on developing means to integrate use of new mobile and interactive technologies into curricula about water. Review by middle and high school teachers of initial work products revealed a need for a context for their use in order to allow for integration of the materials into classroom practice. Following educators' advice, a comprehensive curriculum was developed to engage learners from middle school to university through a collaborative project. Texas Parks and Wildlife Department joined as a major partner and funder in development of the curriculum. Over the course of the project, 15 additional partners and funders joined in the effort which became known as the Texas Aquatic Science Project. The objective of the project became to design an education pathway to create water-savvy citizens of tomorrow who will take personal action to ensure effective stewardship of water and insist on use of factual information to manage water resources. This paper will briefly describe the pathway and present the results of research on the pathway's effectiveness in Texas middle and high school classrooms. A more detailed description of the Headwaters to Ocean Project, and components of the Texas Aquatic Science curriculum and its evolution can be found in Rosen et.al. (2016).

THE AQUATIC SCIENCE EDUCATION PATHWAY

Headwaters to Ocean Project researchers developed an extensive suite of experiential (hands-on and interactive) water educational activities and learning tools for use in classrooms and in experiential informal outdoors settings for student instruction and for teacher training (Rosen et al., 2016). Many of these tools and educational activities were enhanced by integration with exciting and powerful new multi-media and mobile technologies sought by today's youth, such as smart phones and tablets. Educational activities and tools included the following: 1) video- and website-based professional development materials on specific water subjects areas that featured award winning teachers and demonstrations in real classrooms (Gilbert M. Grosvenor Center for Geographic Education, 2010; Rosen, 2013a); 2) an iPad/iPhone app developed for outdoor aquatic science instruction about watersheds and headwaters (Rosen, 2013b); 3) an experiential student learning center, research bed, and water technology demonstration site designed and equipped with state-of-the-art interactive and wireless technology (Rosen, 2012b); 4) a multi-media "command center" designed and built to allow students and educators to participate in real-time expeditions on land and at sea; 5) workshops for educators on how to integrate new mobile technology and outdoors experiential education into their own classes (Rosen, 2011; Rosen, 2012), and; 6) a web-based learning game program about bays and estuaries (Center for Global Environmental Education, 2012).

By mid-2012 project researchers had developed many of the experiential water educational activities and learning tools. Reviews by practicing informal aquatic science teachers indicated strong positive support for the activities and tools. Project researchers also heard from practicing educators that despite high overall quality and usefulness of the individual activities and tools, it was unlikely that either type of materials would receive much use by educators, especially in classroom settings. The reason given by reviewing educators was that teachers in Texas had no instructional context within which to effectively use such materials. This situation is not unique to educational materials about water (Gurney-Read, 2015; Herold, 2015; Wang and Reeves, 2003). Teachers regularly receive a wide assortment of educational materials from multiple sources that cover various subject matter topics to varying degrees of depth, using various styles and conventions, and that may or may not meet specific state standards (Sansom, 2013). For major subject areas having comprehensive textbooks and all-inclusive teaching materials, it may be relatively easy to integrate new materials into a standard curriculum. No standard curriculum existed in Texas for teaching about water and aquatic science, despite requirements and state standards for providing instruction about aquatic science and other water-related subject areas. In response to comment and review of initial educational materials produced, project work expanded with support from 17 partnering organizations and funders to develop a comprehensive curriculum for water education. This work was initially modeled after a similar effort in the State of Missouri (Missouri Department of Conservation, 2006) and became known as the Texas Aquatic Science Project. The term "aquatic science" was used in the name of the project and work products to convey the concept of a comprehensive coverage of water topics and to conform with the terminology used for water education in the Texas state teaching standards.

Work through the Texas Aquatic Science Project resulted in a comprehensive curriculum that adhered to state teaching standards and provided numerous avenues for aquatic science instruction, both in and outside of the classroom. Included is a comprehensive peer-reviewed textbook in print (Rosen, 2014) and available on-line free for use (Rosen, 2012-2017); an extensive teacher's guide with instructional and assessment materials that support integration of technology enhancements available for free download (Johnson, 2013); chapter summary videos on the textbook website with over 110 aquatic science lesson videos also available in closed captioned versions (Rosen, 2015-2017); a website for information exchange and networking about the curriculum and related water matters (Rosen, 2011-2017); and a network of over 65 certified Texas Aquatic Science Field Sites connecting aquatic science in the classroom with informal educators and outdoor place-based experiential learning (Texas Parks and Wildlife Department, n.d.).

The curriculum looks at water and aquatic science from the molecular scale, to aquatic organisms, and on to complete aquatic ecosystems. Activities are designed to guide students through the processes of understanding the characteristics of water molecules that make water unique to life on Earth. They learn that sustainability of water is a priority for all. Chapter lessons begin with an activity that allows the teacher to assess what students know about the subject areas to be studied. Student readings in Texas Aquatic Science include questions at the beginning of each chapter, which help students identify what to focus on in lessons. Each chapter provides multiple opportunities for assessment of student progress. Lessons are structured to provide grade-appropriate depth of coverage and an appreciation for the complexity of water in our lives. Chapter lessons offer a variety of experiential activities in the classroom and in the outdoors. Each lesson includes an opportunity for students to apply what they have learned by synthesizing the information and demonstrating their learning through the development of creative products or experiments. A network of certified field sites provides teachers places to take students and engage them in a variety of outdoor educational contexts and methods for learning about water. Students use science journals, participate in cooperative learning activities, and collect data on a variety of field investigations. Examples include group and personal projects students can do to take action on water sustainability based on facts. Students learn from activities what they can do now and as adults to protect water quality and sustain water use.

The Texas Aquatic Science Project materials and certified field sites now provide a comprehensive context for instruction of middle and high school students. The curriculum also serves as a basis for use of various technology enhancements to learning, and aquatic science instruction at the college level for non-science majors, in the home-school environment, and through on-line opportunities available to anyone.

CURRICULUM ASSESSMENT

A study was conducted throughout the 2015-16 school year to determine the effectiveness of the Texas Aquatic Science curriculum on student learning about aquatic science concepts, the range of implementations of the curriculum into middle and high school classrooms, and which implementation practices worked most effectively.

To recruit teachers for the study, workshops were held for 167 middle and high school teachers representing 4,500 students from schools in all major areas of Texas. Attendees were trained on use of the curriculum in the classroom and then were invited to participate in the research project. From the workshops, 39 teachers participated in the study, with 1,263 students taking part in evaluations. Confidentiality requirements limited evaluation of individual teachers and students over time.

In order to measure the effectiveness of the curriculum for students, tests of overall student understanding and learning about aquatic science based on the curriculum were developed and administered to middle and high school students across the State of Texas enrolled in classes where the curriculum was being used. Students were administered the test at the beginning of the semester in which the curriculum was used and after completing the course of study. Two versions of the test were developed using grade-appropriate questions taken from the teacher's guide: one test for middle school students and one for high school students.

In addition to testing students, a second part of study was directed at teachers to determine how participating teachers integrated the curriculum into their science courses and to determine teachers' attitudes and beliefs about the curriculum as a whole. Three separate means were used to obtain data from the teachers: 1) a baseline questionnaire administered at the beginning of the study, 2) monthly reports, and 3) a post-instruction survey. The baseline questionnaire was developed to receive information about the teachers' background, their classroom and school environment, the teachers' goals for implementing the curriculum into their course(s), teachers' incoming attitudes about the curriculum and teaching in general, and the teachers' demographic information. The monthly report enabled researchers to receive status updates from teachers on how the curriculum implementation was progressing and how teachers felt about the curriculum as the course progressed over the school year. The post-instruction survey was administered after the end of the period of instruction. This final survey was developed to measure teachers' attitudes and beliefs about the curriculum and its implementation, as well as to receive their suggestions for best practices and changes to the curriculum for future iterations.

The results of tests of overall student understanding of aquatic science concepts administered before and after instruction showed that students performed significantly better on the test at the end of the semester than at the start ($F(1,261) = 28.9$, $p < 0.001$). This implies that the curriculum was effective in improving students' knowledge about aquatic science concepts.

Responses by teachers to the baseline questionnaire, monthly reports, and post-instruction surveys indicated teachers maintained an overall positive attitude toward the curriculum, its effectiveness in their classrooms, and its effect on students. Overall, 86% of teachers indicated the curriculum was effective in assisting their students to learn about aquatic science, 79% of teachers indicated that the curriculum was effective in the course of general teaching about science, and 92% of teachers indicated their implementation the curriculum went smoothly.

Many teachers stated that they used both the printed and internet-based materials for instruction. Several teachers indicted lack of access to online resources for their classroom forced them to use only printed materials. Texas Aquatic Science website statistics show teachers throughout Texas are using the curriculum materials for instruction. Patterns of use confirm heavy use of curriculum materials during weekdays when class is in session. The website receives lowest use on Saturday, followed by Sunday, with 80% greater usage on weekdays than on weekend days. Highest use occurs from 8:00 AM to 3:00 PM on weekdays during the school year. Usage when school is out of session is about 75% less than during the school year. There were about 120,000 visits to the website in the 2015-16 school year, the period of study and the first full year the curriculum was available for use in the classroom. Website usage has been 17% higher in the 20116-17 school year, through January 2017.

Teachers in the study also were encouraged to provide accounts of curriculum implementation. In particular, the post-instruction survey asked teachers about their greatest success in implementing the curriculum. A recurring answer from teachers focused around a positive change in students' attitudes, motivations, interest level, and emotions about water. As an example, a teacher in the study stated, "[M]y students truly became more focused on water management. Coming from an agricultural/rural community where our #1 industry is farming and ranching, my students were "aware of water" but not so much their personal ability to impact water usage and quality."

Answers to open-ended questions indicated the following: 1) all of the teachers in the study think the curriculum enhanced their classes, 2) teachers would use the curriculum in their courses again, 3) the curriculum was effective in helping their students grasp their part in conserving water as a valuable resource, and 4) the curriculum was effective in helping their students grasp the importance of water in their lives. In summary, study results reflect a consensus that the teachers felt positively about the curriculum, its implementation in their courses, and its positive effect on students.

CONCLUSIONS

The Texas Aquatic Science Project and curriculum arose after researchers learned that educational enhancements such as an instructional video, smart phone app, interactive learning game, or even many of these taken together, would have little effect on fulfilling the objective of the Headwaters to Ocean project to better educate students about water. Where there is no context for integrating use of technology-enhanced educational materials into a course of study, there will be little or no use by teachers or students. Developing a comprehensive curricula and a context for use of educational enhancements is more difficult, time consuming, and expensive. Our work indicated that building this context for education about water through Texas Aquatic Science now will allow for the integration of technology-based educational products into teaching. But even more important, the new comprehensive curriculum will enable more effective teaching by teachers and better learning by students about water in the classroom and through informal place-based experiential education.

In a short period of time the curriculum's materials have risen to the top of internet searches for aquatic science curriculum, aquatic science book, aquatic science careers, aquatic science videos and other related search terms. Usage of the curriculum's materials spread rapidly and is increasing throughout Texas. The results of research about curriculum effectiveness indicate it was effective in helping students learn about water and aquatic science, and it was generally well-accepted by teachers. Results of research demonstrate the curriculum provides a model education pathway, from headwaters to ocean, for classroom and place-based experiential learning, and for protecting and stewarding water resources.

This model education pathway can be used for developing water education curricula in other locations and for specific areas of instruction, such as for watershed science or coastal areas management. The original objective of the initiating funder has been met. While the direct results over time may be difficult or impossible to quantify, we believe we have developed an education pathway that has the potential to empower future citizens to personally take action on effective stewardship of water and support evidence-based water policies

ACKNOWLEDGMENTS

Meadows Center for Water and the Environment; Harte Research Institute for Gulf of Mexico Studies; Ewing Halsell Foundation; Texas Parks and Wildlife Department; U.S. Fish and Wildlife Service Sport Fish Restoration Program; Missouri Department of Conservation; National Science Foundation Research Coordination Network for Climate, Energy, Environment and Engagement in Semiarid Regions; Meadows Foundation; Texas State High Performance Computing Team; Gilbert M. Grosvenor Center for Geographic Education; Hamline University Center for Global Environmental Education; Texas State Aquarium; Texas Pioneer Foundation; International Crane Foundation; Gary Jobs Corps; Ducks Unlimited, Inc.; The In-Fisherman, Inc.; Welder Wildlife Foundation; Texas Stream Team; Nancy Herron; Sandra Johnson; Randall Maxwell; John W. Tunnell; Larry McKinney; Andrew Sansom; Caleb Harris; Shannon Davies; Steve Quinn; Will Harte; Jackie Moczygemba; Emily Warren; Susan Hankins.

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