Aquatic Science Education Pathway from Headwaters to Ocean is a Model for Place-Based Experiential Learning for Protecting and Stewarding Gulf States' Freshwater and Marine Resources

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ABSTRACT

Teachers, students and parents today have a bewildering and fast-moving array of technology innovations that purportedly will help students learn and teachers teach. Unfortunately, it is hard for anyone to grasp what works, let alone what works best. Texas Aquatic Science has become a model for enhanced water education that has rapidly risen to the top of search engine rankings for aquatic science. The project was conceived in the course of developing means to integrate use of various new mobile and interactive technologies into middle and high school curricula about water from headwaters to the Gulf of Mexico. The researchers heard that to effectively use new technology and materials regularly, there needed to be a context for their use.

Led by educators and researchers from the Meadows Center for Water and the Environment (Texas State University), Harte Research Institute for Gulf of Mexico Studies (Texas A&M University–Corpus Christi), and Texas Parks and Wildlife Department, the initiative expanded through support from over 20 partners and multiple funders to develop that context. This resulted in a comprehensive STEM pathway to engage learners from middle school through adulthood on an educational journey to create water-savvy citizens of tomorrow who will ensure effective stewardship of water in the Gulf states and beyond.

Project partners published a comprehensive textbook available in print and on-line versions, assembled a teacher guide with instructional and assessment materials that allowed integration of technology enhancements, produced videos and enhancement materials, and developed a field site program connecting aquatic science in the classroom with educators and outdoor place-based experiential learning in the field. This provided a comprehensive context for instruction of middle and high school students and served as a basis for aquatic science instruction at the college level for non-science majors, in the home-school environment, and to anyone wanting to learn about nature and water. Curricula met Texas teaching standards for relevant principles of geology, geography, chemistry, physics, ecology, and biology in the text and associated teaching materials. Experience and results of research to-date demonstrate integrating education enhancements into comprehensive curricula enhance student learning and teacher ability to provide meaningful instruction. We believe the model can be used for developing science education curricula in other areas of environmental sustainability, such as for watershed science, land conservation, or coastal areas management.

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INTRODUCTION

In Texas, a rapidly growing human population is placing greater demands on water resources, just as water is becoming more scarce and likely to limit economic growth, business, and stable communities. In some watersheds, more water is promised to upstream users than flows to the ocean (Texas Water Development Board, 2007). Freshwater and Gulf of Mexico aquatic resources are at risk and future conditions are likely to exacerbate current problems caused by low instream flows and pollution. It is common to blame elected and government agency leaders when waters are polluted or become overused. However, such impacts on water are more often a matter of citizens' failure to act responsibly to protect the waters and support or demand effective government and community action.

Studies confirm a crisis in education about water in the U.S., the significance of which is only multiplied as drought conditions worsen across Texas and other arid regions. According to work by an initiative of the Mapping the Future Project supported by the National Institute of Food and Agriculture, educational systems have failed to effectively educate students about the importance of water in our lives (Kushner, 2010). Studies have shown 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), even though water science concepts are generally included in most science education curricula (Ben-Zvi-Assaraf and Orion, 2005), including the Texas teaching standards, known as the Texas Essential Knowledge and Skills (TEKS) (Texas Education Agency, 2016). Many teachers have felt inadequate in their own knowledge about water and how to integrate water education into their own classroom activities (Brody, 1995; Coyle, 2005; Sansom, 2013). Traditional ways of teaching about water have failed to create future citizens who understand the importance of water and advocate its wise use. But there are new ways to reverse the failure to connect people to water.

New work indicates environmental place- and experience-based education helps students achieve standard academic benchmarks and form lasting bonds with the environment (Texas Parks and Wildlife Department, 2010). These education methods are also linked to helping students better understand the world around them and inspire them to pursue careers in science, technology, engineering and mathematics. Sansom (2013) found significant increases in student understanding of the importance of water and teacher interest in instruction about water after having experienced an informal education program about water in Texas. In Sansom's study, 100% of teachers agreed that they accumulated a deeper appreciation for water and water education after they and their class experienced informal instruction at a Texas spring (i.e., the headwaters of the San Marcos River). Results also showed that the place-based experiential education about water can be enhanced by interactive technology, by getting children into direct contact with water, by adding a water 'testing' activity, and by linking the experience in one location to other locations familiar to the children, such as in other waters or towns.

HEADWATERS TO OCEAN—H_2O

In May 2010 the Ewing Halsell Foundation granted funds to the Meadows Center for Water and the Environment (Meadows Center) at Texas State University and the Harte Research Institute for Gulf of Mexico Studies (HRI) at Texas A&M University–Corpus Christi to devise novel experiential, technology-enhanced ways to improve water education for students and teachers, from Texas' headwaters to the ocean. That project became widely known as 'H_2O.' H_2O's immediate goal was to ready various water-related STEM 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 wise water use.

Researchers at the Meadows Center and HRI developed an extensive suite of experiential (hands-on and interactive) water education curricula and learning tools for use out-of-doors and in classrooms for student instruction and for teacher training. Many of these tools and curricula were enhanced by exciting and powerful new multi-media and mobile technologies sought by today's youth, such as smart phones and pads. Following is a listing of the curricula enhancements and tools developed as well as a brief description of use and links to additional information:

Teaching with the Stars

Two units of Teaching with the Stars were produced cooperatively with the Gilbert M. Grosvenor Center for Geographic Education (Gilbert M. Grosvenor Center for Geographic Education, 2010), one on 'watersheds' (Rosen, 2011a) and the other on 'tidewaters' (Rosen, 2013a). Teaching with the Stars units are focused on professional development of teachers through web-based and self-contained videos and associated educational materials. Featured in the videos are award winning teachers and demonstrations in real classrooms. Units are targeted to developing instructor pedagogical knowledge as well as content knowledge in the topic area for grades 6 through 9.

iPad/iPhone App

An iPad/iPhone app was developed for outdoor aquatic science instruction about watersheds and headwaters (Rosen, 2013b) at the Meadows Center available on iTunes (iTunes, 2016a). Featured on the app are an aquatic species identification key (Rosen, 2012a), geographic positioning system (GPS) based photo scavenger hunt (Rosen, 2012b), field journal and student photo collection capability, social-networking ability, educational games, quick response (QR) code scanner, documents, videos, photos, and links relevant to the field site. The app was built to be readily adaptable to new locations.

Experiential Student Learning Center

An experiential student learning center, research bed, and demonstration site was designed and equipped with state-of-the-art interactive and wireless technology (Rosen, 2012c). Now open to about 150,000 visitors per year and 17,000 students on classroom field trips, the center features innovative technologies, a capacity for research (Rosen, 2011b), and demonstration of how to build and operate low cost interactive educational display and learning technologies for use in small-scale outdoor learning centers (Rosen, 2012d). The experiential learning area includes (1) the natural San Marcos Springs where glass-bottom boat rides are offered, (2) a small reservoir called Spring Lake where students can observe aquatic resources and participate in water-related activities, and (3) a 251 acre protected watershed adjacent to Spring Lake. The watershed is crossed by trails and provides an opportunity to develop and test outdoors educational programs focused on the function of sinks and open areas that recharge the aquifer and deliver water directly to the springs (Rosen, 2011c). This area was used as the site of the GPS-based photo scavenger hunt available in an iPad-iPhone app (Rosen, 2012b).

As part of the learning, research and demonstration center, a multi-media 'command center' was designed and built that allowed students to participate in real-time expeditions at sea and on land. The command center accommodated use by scientists who have been able to participate in scientific explorations anywhere in the world remotely using the command center. The command center was designed to be flexible in use, as well as easy and inexpensive to build. This allows simple duplication of the command center for use in small-scale outdoors informal education centers.

The first ever STEM-Corps was supported using H_2O-developed technology and methods. This provided Job Corps student instruction in water, technology, mathematics and additional STEM subject areas and demonstrated added versatility of the technology enhanced water-focused instruction and tools (Rosen 2012e).

Ph.D. Dissertation

A Ph.D. research project and dissertation was supported to examine the educational value of experiential nature education in enhancing learning about water (Sansom, 2013).

Teacher Workshops

Workshops were held instructing teachers how to integrate new mobile technology (Rosen, 2012f) and outdoors experiential education (Rosen, 2011d) about water into their own instruction.

Games

In partnership with Hamline University's Center for Global Environmental Education and the International Crain Foundation, a 40 minute web-based learning game program about Texas bays and estuaries was designed, programmed, and produced (Center for Global Environmental Education, 2012). Four key estuarine species (blue crab, oyster, redfish, and whooping crane) are the subject of learning games, videos, dynamic visualizations, and Google Earth tours.

Website

Developments and updates on the H_2O project were reported continuously throughout the study period in easy-to-read articles, with pictures and links to supporting materials, in a website (Rosen, 2011–2016).

TECHNOLOGY INTEGRATION

By April 2012 the Meadows Center and HRI researchers had made considerable progress developing experiential water education curricula and learning tools for use outdoors and in classrooms for student instruction and for teacher training. At that time the H_2O researchers met with a group of practicing informal aquatic science teachers, including several from Texas Parks and Wildlife Department (TPWD). The purpose of this meeting was to receive input on the continued development and application of the H_2O-produced materials.

The H_2O researchers received highly positive reviews from the assembled educators regarding the numerous H_2O materials. The researchers also heard that despite the overall quality and usefulness of the materials it was unlikely that the materials were to be used by educators, especially in classroom settings. The educators stated that such materials, no matter how well-designed and regardless of source, were rarely used, and if used, were only infrequently used by Texas teachers. The main reason given was because teachers in Texas had no instructional context within which to use such materials. This situation is neither unique nor specific to science subject or water educators in Texas (Gurney-Read, 2015; Herold, 2015; Wang and Reeves, 2003)

Teachers in Texas regularly receive unsolicited educational-technology materials from various sources, including from school administrators who may not comprehensively involve teachers in technology purchasing decisions (Dobo, 2015). Such materials are often produced by corporate sources, government agencies, and non-profit advocacy organizations having probable agendas (Sansom, 2013). Although some of these materials appear unbiased, the materials cover various topics to varying degrees of depth, using various styles and conventions, and may or may not meet TEKS. The materials present instructors with a hodge-podge of information that is generally impossible to string into a coherent pattern of instruction consistent with any curriculum on aquatic science. Yet Texas teachers have requirements to teach aquatic science and closely related subjects. Thus, teachers could use some of the materials if the materials could be coordinated in some fashion within a familiar context or framework for conforming to the TEKS. Given a context or framework within which such materials could fit, including materials being produced by H_2O, the educators felt more of the new curricula and technology enhanced materials would be used in their classrooms.

This discussion initiated the next step in the development of a comprehensive education pathway for aquatic science: the Texas Aquatic Science Project.

TEXAS AQUATIC SCIENCE PROJECT

In September 2012, the H_2O partners added Texas Parks and Wildlife Department (TPWD) to the H_2O partnership as a contributing supporter and developer of enhanced water education materials and research. The goal of the expanded partnership was to develop a comprehensive framework for teaching aquatic science in Texas, meeting TEKS requirements, and providing the context for integrating various curricula and technology-driven water education enhancements into classroom and informal instruction. The expanded project became known as the Texas Aquatic Science Project (TAS). Work on TAS initially focused on developing comprehensive aquatic education guides covering headwaters to the ocean for use by Texas middle through high school students and an educator's guide for teachers.

Modeled after aquatic science guides in use by the Missouri Department of Conservation (2006), the Texas aquatic education guides for students and teachers were to feature instructional units covering all essential aquatic education topics, address grade-level TEKS, offer video enhancements, provide student and teacher resources, and facilitate use of experiential outdoors and classroom education enhancements produced by H_2O and others. The guides would be made available to teachers and students free of charge online and through a variety of dedicated and partners websites.

The TAS ultimately expanded in scope and significance. As TAS expanded it attracted additional partners and donors. A list of the components of TAS follows hereinafter.

Textbook

Anchoring the TAS curriculum for middle and high school students is the peer-reviewed textbook, Texas Aquatic Science, published by the Texas A&M University Press (Rosen, 2014). The textbook is available in print copy and e-book versions. Developed as part of TAS for middle and high school students, the textbook also now serves as a basis for aquatic science instruction at the college level for non-science majors, in the home-school environment, and is open to anyone who wants to learn about nature and water. Aquatic science is covered comprehensively, meeting TEKS for and covering relevant principles of geology, geography, chemistry, physics, ecology, and biology throughout the text and associated teaching materials. Spanning the hydrologic cycle from rain to runoff from watersheds, underground aquifers to springs, and rivers to estuaries, the textbook provides clear, concise scientific information in an understandable and enjoyable way that promotes understanding of important concepts and clarifies major ideas.

Emphasizing water sustainability and conservation actions, the book describes what readers can do personally to conserve water for the future. Professional job and volunteer opportunities for students are provided in illustrated short story format in the hope that some students will pursue careers in aquatic science. Pictured in professional situations are aquatic science workers from diverse backgrounds, with emphasis on workers in under-represented groups.

As Texas Aquatic Science was written, science teachers from throughout Texas were invited to review and comment on each chapter as it was drafted. Nearly 100 individuals participated in review of the textbook. As part of publication by the Texas A&M University Press, the text was submitted to anonymous peer-review. Comments and revisions from Texas educators and peer reviewers were included in the final text.

The textbook is accompanied by an extensive Teacher Guide and a series of specially produced videos covering all of Texas' aquatic systems.

Teacher Guide

The Texas Aquatic Science Teacher Guide (Johnson, 2013) provides teachers the instructional materials and tools to teach aquatic science in the classroom and outdoors. Students are introduced to the wide variety of aquatic ecosystems through science investigations, games, models, cooperative learning activities, Internet projects, readings from Texas Aquatic Science, short videos, science journals, and field based assessments of water quality and environmental conditions in a variety of field trips. The guide supports teachers in their implementation of the TAS curriculum into their classrooms.

Teaching Enhancement Materials

The Teacher Guide is linked to short specially-produced videos which provide an overview of the main ideas in each chapter of Texas Aquatic Science. Activities displayed are designed to be inexpensive and to use materials that are already in most classrooms. Teaching materials for some lessons such as aquatic organism game cards, posters, and videos are contained within or linked to the curriculum guide, and are easy for teachers to download and print or view (Texas Parks and Wildlife Department, 2016).

Standards

All activities are aligned with the state curriculum standards, the TEKS for sixth through eighth grade and for Aquatic Science and Environmental Science courses for high school.

Educational Perspectives

The curriculum looks at water from the molecular scale to the aquatic ecosystems scale, providing activities to guide students through the understanding that the characteristics of the water molecule make it unique in its value to life and that conservation of water and aquatic resources is a priority for all. Lessons have a variety of components.

Lessons in each chapter begin with an activity to allow the teacher to assess what students know about the concepts to be studied. Lessons embed higher order thinking skills, provide depth and complexity of learning, and provide a wide variety of hands-on activities that engage students in a variety of contexts and methods.

Students use science journals, participate in cooperative learning activities, take part in a number of different modes for assessment, and collect data on a variety of field investigations. Science journals provide opportunities for students to record their discoveries, questions, experiments, observations, reflections, label drawings or diagrams, and build data tables and graphs. Systematic records of their work help students develop awareness and understanding of their experiences. Writing down what they see and do helps them to put learning into words. Having the written record helps them review and think about their learning. Science journals also help teachers to be aware of student progress in science skills as well as science concepts. The journal also becomes a tool for helping parents and students understand progress over time.

A variety of cooperative learning activities are included in the lessons. Some things are as simple as designing and conducting investigations in small groups, where students each have a part in work. Other activities include a variety of ways for students to help each other by breaking down tasks into concepts, and then teaching the concepts to the rest of the group.

Assessments

Each chapter provides multiple opportunities for assessment. The first lesson in each chapter provides a formative assessment to help teachers plan for appropriate student learning and to help students focus on what is to come. 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 performances. The student readings in Texas Aquatic Science include questions at the beginning of each chapter, which help students identify what to focus on in the reading. These questions help scaffold the reading level for younger students and provide another type of assessment for the teacher to consider. Student science journals are also useful for formative and summative assessments. Each field trip provides opportunities for performance assessment. At the end of each chapter there are a multiple choice and open-ended questions (with multiple possible answers) for students along with an answer key which may be used as a formative or summative assessment.

Website

The entire text and illustrations of Texas Aquatic Science is duplicated on a website freely available to students and teachers (Rosen, 2012–2016a). The website also contains a video introducing each chapter and links to video aquatic science lessons.

Videos

Teachers and students can access Texas Aquatic Science through 236 specially-produced videos, all available free through various websites and links.

Texas Aquatic Science Chapter Overview and Introduction Videos

Each chapter of Texas Aquatic Science begins with a video, 90 to 120 sec in length, introducing the major concepts and illustrating the ecosystems or subjects that are covered in the chapter. During development of Texas Aquatic Science feedback from reviewers indicated many students have never seen many of Texas' aquatic ecosystems or life in the water. It was felt that video presentation would be the best way to provide an introduction and visual reference point for students to chapter content. These videos are available on the Texas Aquatic Science website and on iTunes (2016b).

Aquatic Science Lessons—Distance Education Video Modules for University and Middle/High School Use

As part of a National Science Foundation (NSF) funded initiative on developing distance education courses on sustainability for South Texas universities, the TAS curriculum became the model for sustainability course development for university use. This added a new supporting partner to TAS, the NSF Research Coordination Network for Climate, Energy, Environment and Engagement in Semiarid Regions (RCN–CE3SAR). The RCN–CE3SAR is made up of 13 research institutes in Texas.[1]

As part of the sustainability courses, 13 chapters of the Texas Aquatic Science textbook are divided into short lessons for use in university-level courses on water for non-science majors. Titled Aquatic Science Lessons, the videos may be used directly in the classroom or indirectly as a distance education course. The lessons are designed for use at different granularity levels, such as a complete chapter, a single subject item within a chapter, or as a stand alone item (image or video). The RCN–CE3SAR has extended work to supporting development of 6 modules: introduction to South Texas, water (Aquatic Science Lessons), air quality, building sustainability environment, sustainability society, and energy.

Aquatic Science Lessons consist of 111 videos without closed captioning and an additional 111 videos with closed captioning for learners who prefer or require captioning. In the lessons viewers are led through the Texas Aquatic Science textbook by the book's author. Each lesson covers a major subject area and is broken down into short sub-topic videos. The video lessons can be used in teaching instruction or for self-education. The 222 videos are arranged into 26 YouTube playlists or as stand-alone videos on educational websites (National Science Foundation Research Coordination Network for Climate, Energy, Environment and Engagement in Semiarid Regions, 2016; Rosen, 2012–2016b; Rosen, 2015–2016; VideoClass, 2016).

TEXAS AQUATIC SCIENCE FIELD SITES

Leading the development of field experiences for students using the TAS curriculum, TPWD has created 'Texas Aquatic Science Certified Field Sites.' The TAS Certified Field Sites are learning centers having outdoor education opportunities, such as zoos, nature centers, museums, aquaria, and state and municipal parks. Participating sites' educators agree to use the TAS curricula and be a rich source of aquatic science experiences and site based activities for visiting students. Each site displays the TAS Certified Field Site seal at their entrance as well as place the logo on the education portion of their website. For the casual website visitor, they place information about the Texas Aquatic Science curriculum, their site designation, and its value in educating students about aquatic science. The educators also agree to attend TAS training, use the TAS textbook and teacher guide activities, and identify site-based activities that support the TAS curriculum. As of March 2016, 60 sites across the state are certified.

TEXAS AQUATIC SCIENCE CURRICULUM ASSESSMENT

In order to assess effectiveness and usability of the TAS curriculum in middle and high school science classes, a two-pronged assessment plan was implemented. In advance of assessment eight teacher workshops were held for 167 middle through high school teachers representing 4500 students in Texas covered by Austin, Dallas, East Texas, Houston, Rio Grande Valley, and San Antonio regions. Teachers were introduced to the curriculum and materials and participated in several Texas TAS activities. All attendees were invited to participate in a pilot project, which facilitated the assessment, evaluation, and subsequent improvement of TAS.

[1]National Science Foundation Research Coordination Network on Climate, Energy, Environment, and Engagement in Semi-Arid Regions member institutes include the Southwest Research Institute in San Antonio; Conrad Blucher Institute, Texas A&M University–Corpus Christi; Harte Research Institute for Gulf of Mexico Studies, Texas A&M University–Corpus Christi; Institute for Water Resources Science and Technology, Texas A&M University–San Antonio; Center for Research on Environmental Sustainability in Semi-Arid Coastal Areas, Texas A&M University–Kingsville; Sub-Tropical Research Center, University of Texas–Rio Grande Valley; Meadows Center for Water and the Environment, Texas State University; Caesar Kleberg Wildlife Research Institute, Texas A&M University–Kingsville; Binational Center, Texas A&M International University; Texas Water Resources Institute, Texas A&M University–College Station; Texas Center for Climate Studies, Texas A&M University–College Station; Institute for Science, Technology & Public Policy, Texas A&M University–College Station; and Center for Housing and Urban Development, Texas A&M University–College Station.

The first portion of the assessment was intended to measure the effect of the curriculum on middle and high school students' understanding of aquatic science concepts, as well as its effect on the students' attitudes and beliefs about aquatic science and the importance of water in their lives. Two grade-level aquatic science conceptual inventories (one for middle school and another for high school) were developed in order to measure students' gains in conceptual understanding of aquatic science. Pre-tests were administered to approximately 900 students from across Texas starting in October 2015. Post-tests will be administered at the end of the courses where the TAS curriculum is being used.

The second portion of the assessment was intended to determine the following: (1) how much and which parts of the TAS curriculum middle and high school teachers implemented in their courses, (2) in what ways the TAS curriculum was implemented into the middle and high school science courses, and (3) what the teachers suggest for future improvements of the TAS curriculum. To accomplish this, teachers submitted monthly reports detailing their use of the TAS curriculum in the previous month, with the reports spanning the semester in which teachers used the TAS curriculum. In each report teachers recorded information about the percentage of their overall curriculum that originates from the TAS curriculum, what sections/chapters of the TAS textbook were employed, the curricular elements they incorporated (e.g., videos, short stories, career connections, video lessons, etc.), whether they used the printed or online version of the TAS materials, the usefulness of teacher guide, and additional input of their choosing. Teachers were also asked to provide input about how the TAS textbook and curricular elements could be improved or changed to allow for easier implementation into their courses. This second portion of the assessment was also intended to gather a repository of effective practices for implementation of the TAS curriculum into middle and high school science courses. Teachers from throughout Texas began submitting monthly reports in October 2015.

While data collection and analysis for both portions of assessment are ongoing, preliminary results indicated that teachers were heavily relying on TAS materials for instruction, and that there was a strong preference for using a combination of printed and online TAS materials. Early reporting has shown a high percentage of teachers indicating that TAS was an effective curriculum, that TAS was effective in enhancing student learning about water, and that teaching enhancements such as videos were useful. Statistics showing patterns of use of the TAS website confirmed heavy use of curriculum materials during weekdays when class is in session. The website received lowest use on Saturday, followed by Sunday. The website received 80% greater usage on weekdays than on weekend days. Highest usage took place from 8:00 AM to 3:00 PM on weekdays during the school year. Summer usage on a day-by-day basis was about 75% less than during the school year. There were about 220,000 visits to the website in the 2015–16 school year, the first full year TAS was available for use in the classroom.

SUMMARY AND CONCLUSIONS

Teachers, students and parents today have a bewildering and fast-moving array of technology innovations that purportedly will help students learn and teachers teach. Unfortunately, the reality is that it is hard for anyone to grasp what works, let alone what works best. Yet funders, corporate sponsors, government agencies, university researchers, and many others are producing and promoting a continuous stream of education technology applications for teachers—some with obvious bias and some uncompromised. After following this well worn path, the Meadows Center and HRI developed and presented a new array of technology-enhanced educational aids to a group of water science teachers only to be told that the new items were exciting, but would probably not be used by teachers. Besides questions about effectiveness, the developers heard that to effectively integrate the new materials, games, videos, interactive media, and apps into teaching that there needed to be a context for use. For water education in Texas, while there were state requirements to teach the subject, there were as yet no comprehensive curricula within which to do that. The project partners then developed that context by publishing a comprehensive textbook available in print and on-line versions, assembling a teacher guide with instructional and assessment materials that allowed integration of technology enhancements, producing videos and enhancement materials, and developing a field site program connecting aquatic science in the classroom with educators and outdoor place-based experiential learning in the field.

Developing a single app, a game, a new video, and so on is simple. Funding is available for doing so, and entrepreneurs are ready to sell such applications to school districts, teachers, and parents. But where there is no context for integrating use of the product into a course of study, even where the product might be useful, there will be little or no use. Taking the extra steps to develop curricula and a context for use of education enhancements is more difficult, time consuming and expensive. Our work indicates that building this context for education and integration of technology into teaching, in the classroom and for informal place-based education can be effective and may be necessary.

In only a short period of time TAS has risen to the top of internet searches for aquatic science and curricula, book, information, guide, website, videos and other related search terms. Usage of TAS materials has increased and spread rapidly throughout Texas. Our experience and results of research to date demonstrate that TAS provides a model education pathway, from headwaters to ocean, for classroom and place-based experiential learning, and for protecting and stewarding freshwater and marine resources. We believe the model can be used for developing science education curricula in other areas of environmental sustainability, such as for watershed science, land conservation, or coastal areas management.

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