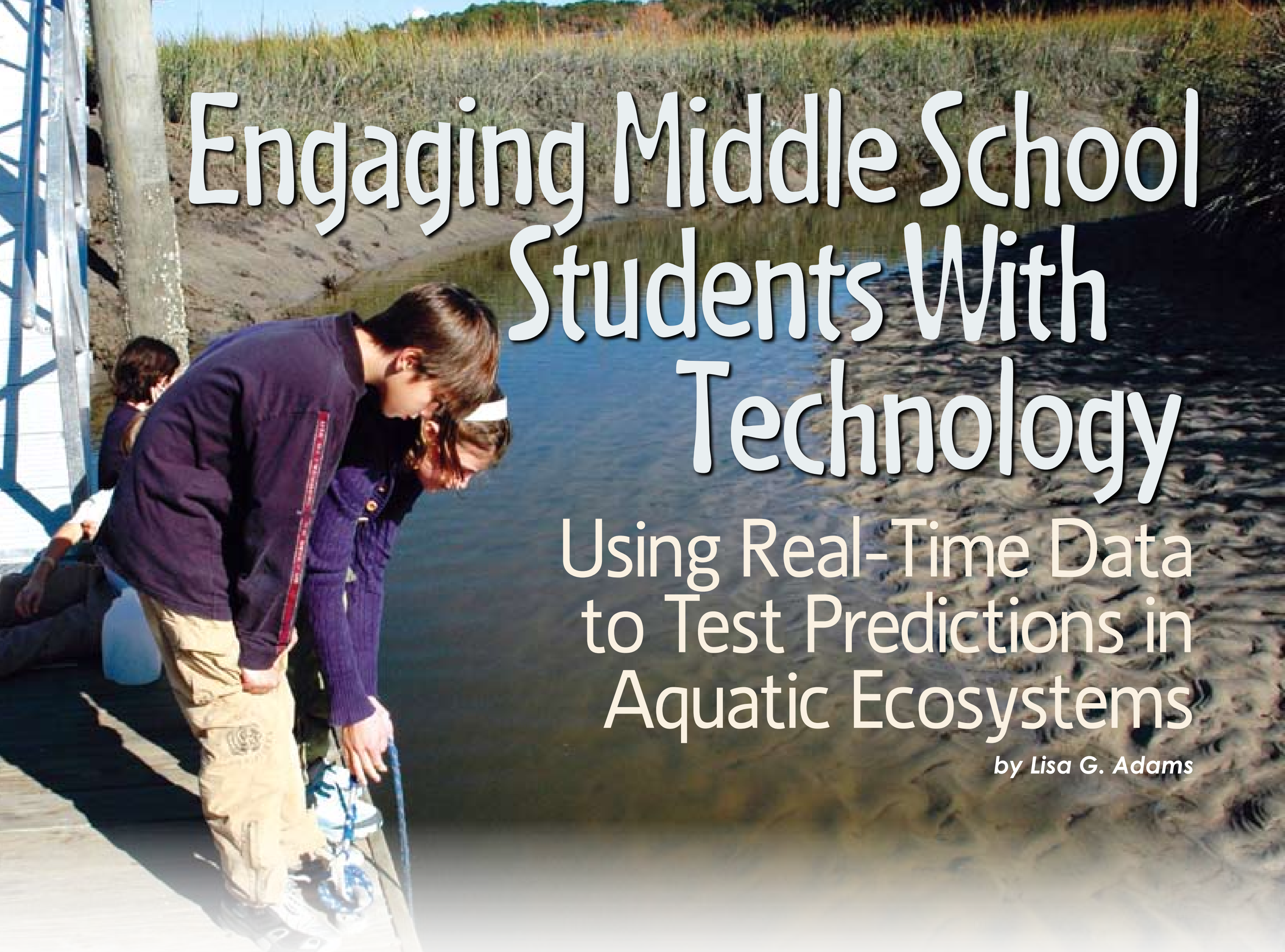


Engaging Middle School Students With Technology

Using Real-Time Data to Test Predictions in Aquatic Ecosystems

by Lisa G. Adams

Achieving scientific literacy requires that our students investigate the natural world using technology. The internet is an everyday technology with which our middle and high school students have experience; according to Lenhart and Madden (2007), 93% of teens are internet users, and their use is intensifying. As science educators, we can take advantage of teen internet savvy and redirect students' online travels toward exploration of our environment through streaming real-time data (RTD). The advanced monitoring technology in our coastal buoys and orbiting satellites used by universities and government agencies allows students to effortlessly investigate the natural and physical world around them. Studies have shown that using RTD not only adds relevancy to their learning experience but also engages students in scientific investigations (Parsons 2006; Adams and Matsumoto 2009). A better understanding and appreciation of our environment will help build a scientifically literate generation, which is crucial for our society to successfully deal with the environmental issues we face.

Using real-time data sets: General classroom tips

All data collected from the environment are considered authentic data and are categorized by the age of the data set. Data sets are considered RTD when the data are disseminated within hours to days of their collection; near-real-time data when the data are roughly within months of their collection; and archived data when the data are older than several months. However, both real-time and near-real-time data are generally referred to as RTD, and in most cases, students use near-real-time data. The authenticity and real-world nature are the important attributes of the data, not the age of the data set. For simplicity, I will refer to both real- and near-real-time data from here on out as RTD. Teachers may prefer to use data sets they have retrieved themselves; for example, if classroom internet capabilities are limited, the instructor can easily download data sets prior to class and have them available for student use (see Resources for data sources).

Parsons (2006) evaluated the use of RTD in the K–12 classroom and found visualization tools were important in the learning process. Due to the technology involved in environmental monitoring and the fact that data stream from faraway places, students can experience a disconnection between the RTD stream and the environmental setting from which it comes. Photographs downloaded from the internet allow students to connect a distant sampling location with its associated data set, which will help them to fully appreciate and understand the physical and chemical nature of the data. The use of such images is even more important for younger students, who may not be well traveled and lack geographic references for these environmental settings.

RTD not only offer information that allows student testing and interpretation; they also convey the importance of technology to science and address the content standard of Science and Technology (NRC 1996). Discussing the technology of the instruments and sensors used in the data collection reinforces the importance of technology in the acquisition of information that allows scientists and students to better understand their environment. The Southeast Coastal Ocean Observing Regional Association and the Central and Northern California Ocean Observing System have background information and educational modules, respectively, on instrument and sensor technologies that may be useful to teachers (see Resources).

Using RTD to test predictions

Redirecting the curious nature of middle school students toward attaining answers to their own science-related queries using RTD is easier than one may think. A plethora of data exists at the touch of a keypad, and guiding our students in this journey of scientific discovery engages them in the science, technology, engineering, and mathematics disciplines. The activity described here was designed to let students use real data sets to investigate tidal creeks and how they differ from freshwater creeks, thus promoting skills necessary for achieving the Science as Inquiry standards (NRC 1996).

The activity took place at the Coastal Discovery Museum located in Hilton Head Island, South Carolina, which was the site of a previous tidal creek monitoring project that was carried out by the author. The museum highlighted the Jarvis Creek Monitoring Project as one of the sessions offered to a local middle school as part of the museum's Barrier Island Education Program. As the principal investigator of the Jarvis Creek Monitoring Study and a university professor who focuses on aquatic monitoring and educational applications of RTD, I was asked by the museum to develop middle school curricula that highlight the monitoring study and help guide students through the aquatic inquiry activity.

The entire activity lasted roughly two hours and could easily be broken up into two or three class sessions. Computers were not used at the museum; students were provided all of the necessary information on the Moon phases, tide charts, maps, and data sets. Student use of RTD is not dependent upon internet access; teachers can access the data set and print it prior to class. Teachers who are uncomfortable explaining possible anomalies could then review the data prior to the exercise. There are many sources of data for both freshwater and saltwater systems (see Resources).

Science in Personal and Social Perspectives content standards (NRC 1996) were addressed by this investigation due to the local nature of the tidal creek, which is located just a few miles from the students' school. The freshwater creek was also sampled prior to the actual activity and presented to students so that they could visually compare the water from the two creeks (Figure 1). Because the students' school is also located just minutes from the ocean, a jug of ocean water was provided for further comparison. Pictures of the freshwater creek, which is located 300 miles inland from the tidal creek, were available for students to view and posted on a bulletin board during the activity. These images provided a sense of place for the remote data collected from the freshwater creek.

Geographic and content modifications

There are many alternative approaches to this activity that teachers can implement in their classrooms depending on the geographic setting of their school and the subject matter being studied. Focusing strictly on freshwater systems is an easy modification to this activity, as is addressing environmental issues facing most watersheds. Students could undertake this activity in a classroom without field trips or water samples, relying just on data sets provided by the teacher or accessed via the internet.

Aquatic investigations can be a cross-disciplinary quest for middle school science students covering the water cycle, tides, and Moon phases in Earth science, runoff issues in environmental science, chemical and physical

FIGURE 1 Water samples from the freshwater creek, tidal creek, and Atlantic Ocean

characteristics of water in chemistry, and the ocean in Earth and life sciences. Needless to say, the possible content connections are endless and can be adapted to any classroom, geographic location, or focus of interest.

In a previously published tidal data activity, Trundle (2007) focused on one location and based the time period of the data collection on the birthdays of her students and then allowed them the freedom to choose a second location based on family vacations. This was a creative way to add a personal connection for students during their exploration. If you are apprehensive about potentially having to explain regional variations in water data, then limiting the data retrieval to one geographic site for each type of water will simplify data interpretation.

Data sets from local watersheds add another dimension of relevance to the investigation. The added value of geographic proximity to the data set will also add significance to the learning experience. Instead of focusing on tidal creek processes, inland schools may want to select a river or lake and study seasonal differences in freshwater systems. If a class were interested in focusing solely on its own watershed but wanted to look for temporal differences such as seasonal effects, having students study their birthdates, similar to Trundle's activity (2007), and then sharing various trends across the seasons would be a great modification of the activity. For example, trends in water temperature or dissolved oxygen could be tracked over the year based on students' birthdays, which would tie nicely to climate discussions, as well as seasonal changes in lakes or coastal bodies based on primary productivity.

An alternative question for students to address using RTD would involve land-use patterns and how they affect water. Students could make predictions regarding how land-use patterns affect certain water-quality parameters. For instance, conductivity or turbidity may be of interest for runoff issues regarding development, while nutrients and oxygen may be of interest if agricultural practices are being investigated. RTD can be accessed from the United States Geological Survey for streams that vary in their proximity to industry or farmland. Not only would students be actively learning about surface runoff issues and water quality, they would, even more importantly, be engaged with a current environmental issue that affects all watersheds.

Finally, the data collected from water monitoring sites are evaluated and used by many stakeholders. A major purpose for observatories or monitoring agencies is to share their data with the goal of educating and engaging students, stakeholders, and the public. Therefore, researchers would more than likely welcome student queries about their data, which would add yet another level of relevancy to students' learning experiences.

Student-generated questions

Students were first introduced to freshwater and coastal monitoring through data sets, photographs, maps, instruments, and sensors. After learning about the Jarvis Creek Monitoring Project that took place at the museum just months before their visit, students were able to go to the floating dock where the water monitor was previously deployed and collect a jug of water so that they had a visual for the tidal creek data (see opening photo).

After this short introduction to water monitoring and trip to the dock, students were asked to generate at least one question they had about either tidal creeks or how tidal creeks compare to freshwater creeks. A whiteboard was provided, and students wrote their questions on it (Figure 2). A discussion followed concerning how certain questions were good, but their answers were unattainable due to a lack of information or time. The class selected which questions could be investigated using the information provided on their data board, which was a standard-sized bulletin board that presented watershed maps of the two study sites, tide tables, and actual data tables (RTD) from the freshwater creek and the tidal creek (Figure 3). The data for both creeks included the date and time of the collection, pH, salinity, conductivity, dissolved oxygen, and temperature readings.

Reviewing the data and student interpretation

After reviewing the data and information available, students were asked to refine their questions if necessary, based on the informational sources that were available. The questions shared a repeating theme of salinity, which implied students had some basis for predicting that there was a salinity difference between the two creeks. However, the goal of this activity was to get students to analyze data and interpret trends or information that explains the causal relationship in their predictions. For example, if they believed that the salinity fluctuates over time in a tidal creek but not in a freshwater creek, their charge was to explain what causes the salinity to change over time. Once students analyzed the data, the numbers clearly showed this phenomenon, but when asked to further delve into the proposed relationship, the task became a bit more challenging.

Often students are presented with a relationship that characterizes a system without being offered the opportunity to explore the source of its cause. Most middle school science lessons regarding aquatic ecosystems involve presenting a list of characteristics for each type of aquatic ecosystem. More specifically, students may learn that tidal creeks and estuaries can fluctuate in various chemical and physical parameters over time, while freshwater bodies of water do not vary as much as their coastal counterparts. This type of passive learning doesn't reflect the true nature of science, a powerful tool to explore the natural and physical world. In this activity, students are guided to explore what natural and physical factors contribute to the differences between tidal creeks and freshwater creeks by analyzing real data sets as opposed to passively reading about the water cycle in a textbook. Asking students to investigate why some bodies of water change over time, in a cyclic pattern while others do not creates a student-based learning experience that is more enriching and meaningful. This activity led students to use Earth science data sources such as tide tables, Moon-phase calendars, weather logs, and maps that provided the data and information necessary to explain why various parameters changed over time in one creek rather than in both the freshwater and tidal creeks.

FIGURE 2 Whiteboard with students' questions about tidal creeks

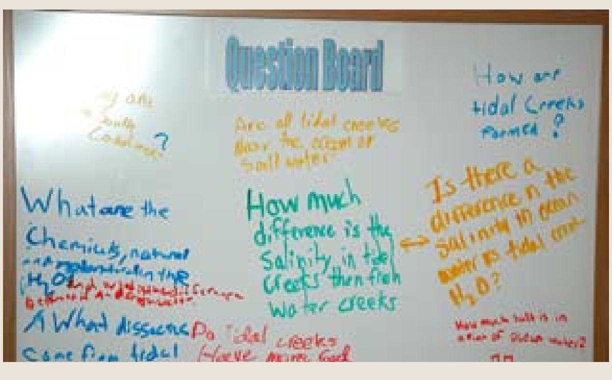
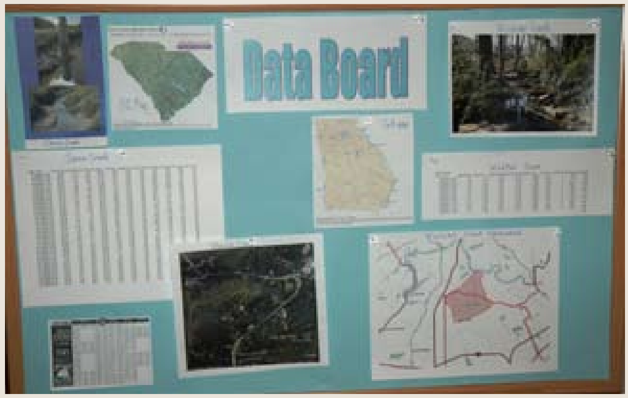


FIGURE 3 Data board containing photographs of study sites, RTD, watershed maps for the freshwater creek and the tidal creek, as well as a tide table and aerial map for their regional body of water



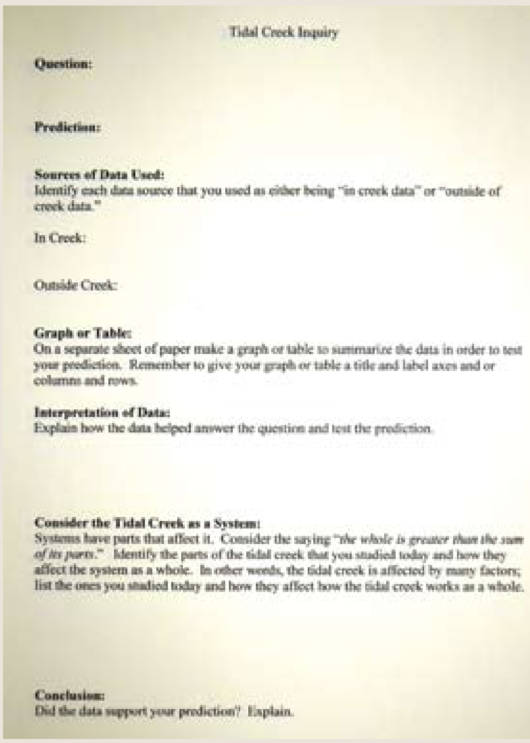
Having this type of guided learning in our classrooms addresses many of the national science standards involving the Nature of Science and Technology (NRC 1996). Photography, the internet, satellites, GIS, instruments and sensors, weather monitors, and computers are just some of the types of technology that could be utilized in this learning quest. The valuable information provided by these technologies (Science and Technology standards, NRC 1996) allows students to successfully identify and explain factors that influence the cyclic patterns of salinity observed in the tidal creek.

Student learning and assessment

Keeley (2008) described whiteboarding as a strategy for promoting student learning and assessment in the classroom. In this activity, whiteboarding was successful in eliciting the prior knowledge of students about tidal creeks and generating ideas. The nonpermanent nature of the board encourages students to write ideas that they may be unsure of, which in this activity translated into questions. Students were able to communicate their questions with their peers using the whiteboard and were encouraged to pair up in their investigation based on similar interests and predictions. The whiteboard served as a focal point, resulting in a seamless transition between posing questions and investigating using the RTD available to them. An activity worksheet (Figure 4) led students through this interactive lesson, and their charge of using the data to test their prediction was easily attainable. Most students chose to either examine the salinity differences between the two creeks or how salinity changes over time in the tidal creek.

Students were prompted to decipher whether the data they used to test their prediction came from within the creek, i.e., the water-quality data, or outside of the creek, i.e., watershed maps and tide charts. These questions pertain to the Unifying Concepts and Processes standards, which in turn pertain to Systems (NRC 1996) and address how a system, like a tidal creek, is affected by many factors, such as the incoming and outgoing

FIGURE 4 **Tidal creek student activity worksheet**


Tidal Creek Inquiry

Question:

Prediction:

Sources of Data Used:
Identify each data source that you used as either being "in creek data" or "outside of creek data."

In Creek:

Outside Creek:

Graph or Table:
On a separate sheet of paper make a graph or table to summarize the data in order to test your prediction. Remember to give your graph or table a title and label axes and or columns and rows.

Interpretation of Data:
Explain how the data helped answer the question and test the prediction.

Consider the Tidal Creek as a System:
Systems have parts that affect it. Consider the saying "*the whole is greater than the sum of its parts.*" Identify the parts of the tidal creek that you studied today and how they affect the system as a whole. In other words, the tidal creek is affected by many factors; list the ones you studied today and how they affect how the tidal creek works as a whole.

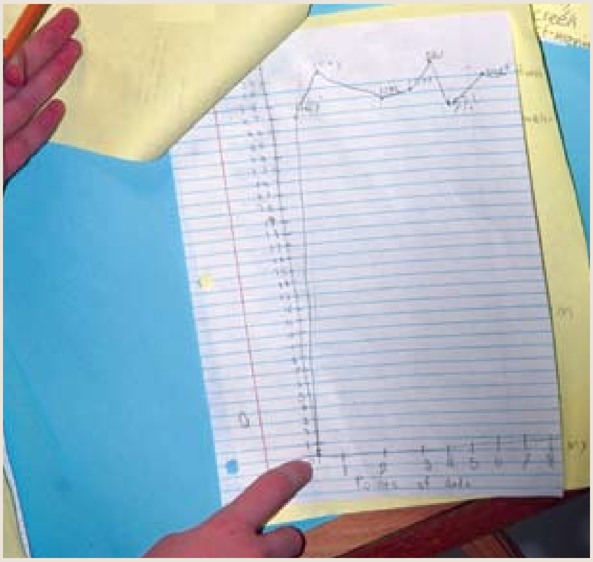
Conclusion:
Did the data support your prediction? Explain.

tides and Moon phases. Actually having the opportunity to trace and track the path of each creek reinforced the rationale behind students' initial prediction of salinity differences between the two creeks. Using the maps provided, students observed firsthand the connected nature of the tidal creek with the estuary and ocean as opposed to the lack of coastal connection with the freshwater creek. This realization of the marine influence on tidal creek dynamics was experienced by students and, therefore, naturally led them to compare the salinity peaks and valleys observed in the tidal creek data set with the tide charts. This stepwise process of requiring students to use the data, maps, and charts enabled them to fully appreciate how tidal creeks behave as systems that are affected by factors such as the ebb and flow of the tides. The instructor's role is as a facilitator, leading students to the data in order to answer their question, which empowered them to fully explain why there were cyclic patterns of salinity fluctuations in the tidal creek as opposed to the inland freshwater creek, which lacked a saltwater connection.

Each group of students was asked to share their question, describe the data used to test their prediction, and make a conclusion regarding whether their data supported their prediction, which addressed the Nature of Science standard (NRC 1996). Some chose to present their findings in a table format, while others presented their data using a graph. Figure 5 shows one student explaining the plotted daily cyclic salinity pattern of the tidal creek. The graphical presentations of the tidal creek data required students to apply earlier mathematical skills acquired in elementary school involving spotting patterns and trends, such as the cyclical nature of the salinity graph (AAAS 1999). Yeh and McTigue (2009) reported that in order for students to be successful in standardized state science tests, they needed to be able to produce and interpret graphs.

These middle school students were able to interpret the RTD and graphically present their findings. Generally, students were better able to verbally describe these relationships than to graph them or present them in a table format. The criteria for evaluating student comprehension and capacity to explain how tidal creeks operate like systems required students to articulate the influence of factors like the Moon's effect on tides, or the tidal cycle's affect on salinity. The criteria for evaluating student understanding and competence in successfully being able to translate this relationship using the data required students being able to present their findings either graphically or in table format,

FIGURE 5 Student sharing his graph showing the salinity changes over time in the tidal creek



which was a more challenging task for them. For example, when students were asked to interpret the data, there were some inconsistencies between their written and verbal explanations and their graphs and tables. Students' written and verbal responses were more accurate than their graphs and tables, although, in their submitted answers on the worksheet, they referenced the need for the data in order to understand the relationship. For instance, when asked to interpret the data with a response to the prompt "Explain how the data helped answer the question and test the prediction," students offered some interesting replies, such as "Salt on a graph helped us to confirm tides," or "I need data. Without it, you don't know much of anything about it," or "The data sheets told us how much salinity was in the water." These responses indicated a realization that data collection and interpretation are important processes that allow us to better understand the natural world. When asked to represent their data graphically or in tabular form, students exhibited some difficulties accurately assigning the variables (salinity and time) to the appropriate axes, completely labeling the axes with units, and providing a title for the graph or table.

The disconnect between students realizing the need for the data in order to understand the relationship between the variables and their ability to correctly graph the data highlights the need for middle school students to be presented with more opportunities to independently design graphs and tables. The challenge of having students choose appropriate data to test their prediction, incorporate the data set, illustrate the results graphically or in a table, and verbally describe how the data explain the proposed relationship stated in their prediction emphasized the importance of data collection to the scientific process. This step of using the data to explain a relationship either proposed or already accepted is paramount for student success in terms of understanding and appreciating the true nature of science, and students should be able to experience this type of exercise more often than they currently do. This active participation may encourage a deeper thought process and result in students asking more questions as they begin to have a deeper understanding of the natural and physical world around them.

Conclusion

Throughout the activity, I watched students develop a deeper understanding of how many factors affect tidal creeks, such as the Moon phases and tides, precipitation, and the fact that tidal creeks connect freshwater and marine systems. Having these RTD available allowed students to explore their own surrounding aquatic ecosystem (Life Science content standard, NRC 1996) and actually learn firsthand why there were differences in the salinity levels between the two creeks. A sense of ownership and pride was heard in their presentations, indicating a deeper appreciation for their watershed.

Technology allows us to bring the babbling brooks, raging rivers, serene lakes, fluctuating tidal creeks, dynamic estuaries, and ocean basins into our classrooms, whether they are 1 mile or 1,000 miles away from our schools. Data can stream live or be downloaded at the touch of a keypad, and students can ask questions that relate to their watershed or explore deep ocean basins using RTD. These meaningful learning experiences that use genuine data sets to answer student-generated questions provide students with a higher level of understanding of the complicated nature of aquatic systems, which is essential for the next generation when dealing with major environmental issues facing our aquatic ecosystems. Teaching science using the natural world as the data stream may be the best application of technology that middle school educators can tap into and may serve as the engagement carrot for our students and possibly be the key to retaining their interest in science. ■

Acknowledgment

Support for the Jarvis Creek and Wild Cat Creek Monitoring Studies came from Kennesaw State University Mentor Protégé Grants. I would like to thank the staff at the Coastal Discovery Museum, in Hilton Head Island, SC, including Natalie Hefter, Amy Tressler, and Carlos Chacon for their support of the Jarvis Creek Monitoring Program in 2008 and their invitation to be a part of the Museum's Barrier Island Program. I would also like to thank Dr. Jennifer Frisch, assistant professor of Biology Education at KSU for her thoughtful review of this project.

References

Adams, L.G., and G.I. Matsumoto. 2009. Enhancing ocean literacy using real-time data. *Oceanography* 22 (2): 12–13.

American Association for the Advancement of Science (AAAS). 1999. *Benchmarks for science literacy. www.project2061.org/publications/bsl/online.*

Keeley, P. 2008. *Science formative assessments: 75 practical strategies for linking assessment, instruction, and learning*. Thousand Oaks, CA: Corwin Press.

Lenhart, A., and M. Madden. 2007. *Teens, privacy, and online social networks*. Washington, DC: Pew Internet and & American Life Project. *www.pewinternet.org/Reports/2007/Teens-Privacy-and-Online-Social-Networks.aspx.*

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academies Press.

Parsons, C. 2006. *SWMP/IOOS real-time data in K–12 classrooms: A front-end evaluation*. New Brunswick, NJ: Rutgers Institute of Marine & Coastal Sciences and Jacques Cousteau National Estuarine Research Reserve.

Trundle, K.C. 2007. Acquiring online data for scientific analysis. In *Technology in the secondary science classroom*, eds. R.L Bell, J. Gess-Newson, and J. Luft, 53–62. Arlington, VA: NSTA Press.

Yeh, Y.Y., and E.M. McTigue. 2009. The frequency, variation, and function of graphical representations within standardized state science tests. *School Sciences and Mathematics* 109 (8): 435–49.

Resources: Real-time data

Estuarine monitoring

Environmental Protection Agency's National Coastal Assessment—*www.epa.gov/emap/nca/html/regions/index.html*

National Estuarine Research Reserve System—*http://nerrs.noaa.gov*

Instrument and sensor technology modules

Central and Northern California Ocean Observing System's interactive module on ocean observatory technology—*www.cencoos.org/sections/classroom/observing.shtml*

Southeast Coastal Ocean Observing Regional Association's Observing technologies for the classroom—*http://secoora.org/classroom/technologies*

Moon phases, tides, weather

Moon-phase information from NASA—*http://eclipse.gsfc.nasa.gov/phase/phase2001gmt.html*

Real-time weather data for various estuaries and buoys from the National Weather Service—*www.ndbc.noaa.gov*

Tide predictor and processor supported by the University of South Carolina—*http://tbone.biol.sc.edu/tide*

Ocean observing

Adams, L.G., and G.I. Matsumoto. 2007. Investigating coastal processes and nitrate levels in the Elkhorn Slough using real-time data. *Oceanography* 20 (1): 200–04.

The Integrated Ocean Observing System's site mapping all of the coastal and Great Lakes observing sites in the nation—*www.ioos.gov/catalog*

Murray, L., D. Gibson, and A. Ward. 2008. Real-time ocean data in the classroom. *The Science Teacher* 75 (7): 44–48.

Ocean science education network

Centers for Ocean Sciences Education Excellence's network comprises 12 regional centers with the overall mission to "spark and nurture collaborations among research scientists and educators to advance ocean discovery and make known the vital role of the ocean in our lives"—*www.cosee.net/about/aboutcenters*

Water-quality monitoring

The Environmental Protection Agency's (EPA) site focusing on monitoring and assessing water quality—*http://water.epa.gov/type/watersheds/monitoring/monitoring_index.cfm*

The EPA's site where students can learn about their own watershed and view maps that can be potentially associated with real data sets—*http://cfpub.epa.gov/surf/locate*

The United States Geological Survey has a wealth of information on the nation's bodies of water, ranging from RTD to maps and coverage of current water studies—*http://water.usgs.gov*

Lisa G. Adams *(ladams@kennesaw.edu)* is an assistant professor of biology and biology education in the Department of Biology and Physics at Kennesaw State University in Kennesaw, Georgia.