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Integrating Technology into Science Field Investigations

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Abstract

One of the most valuable results of environmental education is the clear association between understanding of STEM (science, technology, engineering, and math) concepts after participation in outdoor programs, as outlined in the National Science Foundation's Environmental Science and Engineering for the 21st Century report (NSF, 2000). One component of STEM is technology. Technology can assist in "problem solving, consensus building, information management, communication, and critical and creative thinking", the main goals and missions of environmental education as stated by the NSF report. These tools allow students to participate in science as a scientist would. By using appropriate technology, and developing technological skills along the way, students will be better prepared for career paths to be created in the future that will inevitably utilize technology. In order to maximize potential gains of using both technology and environmental education, technology must be used in concert with outdoor hands-on experiences, and not just as an afterthought (Willis, Weiser, & Kirkwood, 2014). This paper aims to share best practices of methodology for field investigations, along with examples of technology integration for each portion (preparation, action, and reflection).

In The Field

A class of students is split into groups, and is exploring a salt marsh within the Chesapeake Bay's watershed. Each small group is focused intently on the task at hand, to conduct a transect study of the marsh, determining what plants and animals can call it home. Students are using tools such as hand-held Global Positioning Systems (GPS), transect lines, quadrats, and digital cameras to document their work. With each student assigned a specific task, they work together to collect their data, and then back in the classroom, share the information about their area with the entire group in order to create a habitat map of the entire marsh. While conducting real-world science in an outdoor setting, with common and new technologies, students are engaged and interested in the topic at hand.



Figure 1: Salt Marsh Investigation



Figure 2: Side by side in the lab



Figure 3: Refractometer use

The benefits of students participating in environmental education are vast, and have been studied in great detail (Bartosh, 2004; Louv, 2005; US Senate, 2011). One of the most valuable results of environmental education is the clear association between understanding of STEM concepts after participation in these outdoor programs, as outlined in the National Science Foundation's Environmental Science and Engineering for the 21st Century report (NSF, 2000). In the report, NSF cites similar learning goals and missions in environmental education and in STEM programs, thus strengthening students' understanding of these concepts such as "problem solving, consensus building, information management, communication, and critical and creative thinking" during participation in both. Outdoor experiences foster these skills as well as added benefits such as a sense of stewardship and appreciation for nature (Broussard, Jones, Nielsen, & Flanagan, 2001), and additional opportunities for students to interact with technology (Hougham, Eitel, & Miller, 2015).

The North American Association for Environmental Education (NAAEE) partnered with Stanford University to review 119 studies on the impacts of environmental education. The 2017 Stanford study presents several key findings including:

- 98% of studies that examined whether students gained knowledge from environmental education saw a positive impact,
- 90% reported increased skills; and,
- 83% reported enhanced environment related behaviors.

Lead researcher, Dr. Nicole Ardoin from the Stanford University Graduate School of Education and Woods Institute for the Environment, stated "There is a mountain of evidence that suggests environmental education is a powerful way to teach students. Over 100 studies found that it provides transformative learning opportunities. There is no doubt that environmental education is one of the most effective ways to instill a passion for learning among students" (Ardoin, 2016). The research shows the many benefits of environmental education in addition to science knowledge, including academic performance, critical thinking, civic engagement, and personal growth.

Technology can also provide benefits to environmental education programs. The Virginia Standards of Learning (SOLs) state that "one must expect to 'do as a scientist does' and not simply hear about science if they are truly expected to explore, explain, and apply scientific concepts, skills and processes" (VDOE, 2010). Interactive technology, when used appropriately in order to accomplish learning goals, can support and enhance the project by allowing for the development of technology skills, addressing different learning styles, engaging students in more personal work, and supporting multidisciplinary learning

(Willis, Weiser, & Kirkwood, 2014). Technologies used in place-based education programs allow students to collect local observations both in physical locations and digitally, generate their own research and information, and connect their local environment with others (Hougham et al., 2015). Technology must be used in concert with outdoor hands-on experiences though, in order to reap the benefits of both it and environmental education, while also preparing students for the future (Willis et al., 2014).

MWEEs

In the Chesapeake Bay region, much of the effort in providing students with outdoor educational experiences has taken the form of MWEEs. The term MWEE, meaningful watershed educational experience, was coined by the Chesapeake Bay Program Education workgroup, in part due to the creation of the Chesapeake Bay Agreement in 2000 (Chesapeake Bay Program Education Workgroup, 2014). The Agreement tasked schools with providing a meaningful Bay or stream-focused outdoor experience for every student in the watershed prior to their graduation from high school (Chesapeake Executive Council, 2000). In 2014, the Chesapeake Agreement was reauthorized, and an environmental literacy goal was added, specifically increasing the MWEE requirement to one MWEE for every student during each phase of their education — elementary, middle, and high school (Chesapeake Executive Council, 2014).

MWEEs support classroom teaching and learning by involving students directly in field investigations, through development of a research question, collection of data, and analysis of results. The MWEE process is not a one-day event, but rather a year-long process involving the Standards of Learning (SOLs) as well as other education initiatives such as the Next Generation Science Standards. To achieve this standard, organizations and schools must fit the following requirements (Chesapeake Bay Program, 2014):

First, students must decide on an environmental issue or question to research, setting up experiments, and reviewing background information. Then, during the action phase, students participate in outdoor field experiences to collect data and participate in project to address environmental issues. Finally, during the reflection phase, students compile and analyze data, make conclusions, and participate in projects to address environmental issues. When done properly, MWEEs bridge together multiple disciplines, increase student knowledge, and increase positive behaviors and attitudes regarding the environment (Chesapeake Bay Program Education Workgroup, 2014).

CBNERR

The Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERR or Reserve), located at the Virginia Institute of Marine Science (VIMS), was designated in 1991 as one of 29 NERR sites established to promote informed management of the Nation's estuaries and coastal habitats. A critical aspect of the National Estuarine Research Reserve System (NERRS) mission is to enhance public awareness and understanding of estuarine areas and provide suitable opportunities for public education and interpretation. Reserve educators have created an established education program, coordinating many informal science programs for K-12 students, teachers, and the general public. CBNERR educators use technology to enhance field investigations with K-12 students through the use of many different tools (Figure 4). Students participating in field investigations may use the technology in any or all of the three phases of a MWEE, and by using the same tools as scientists, are gaining exposure to possible careers in the future.

Technology Use in the Preparation Phase

In the preparation phase of a MWEE, students develop their investigative question and complete background research to prepare for the main outdoor field experience. This component could involve outdoor experiences, but typically takes place in the classroom and prepares students for outdoor investigations. For students that may not be comfortable in the field, it is beneficial to introduce them to the location as much as possible. This allows students to focus more on data collection in the field, and decreases the distraction of being in a new environment.

Students may not be familiar with particular estuarine habitat types, and it may not be possible to take students to research locations. Therefore, we prepare students for field experiences in part through the use of videos and virtual reality. Videos and virtual reality can transport students virtually to a location they otherwise would not be able to visit. There are endless opportunities for this, but we recommend several that relate very well with Chesapeake Bay MWEEs. For general estuary information, we suggest the NERRS Estuary Education website (<https://coast.noaa.gov/estuaries/>). This site provides introductory videos on topics such as watersheds, estuaries, animals and plants, food webs, etc. In addition to watching videos, students could make their own informative video to share with their classmates, or students could contact local experts who can video chat and answer questions in order to shape their investigation.

A further step would be to use virtual reality, transporting students virtually to key habitats they are discussing in class through the use of Google Cardboard (<https://vr.google.com/cardboard/>) or similar

technology. Educators or field staff collect video while conducting research in the field, and then we share those videos, including sound, with our students. Being transported to the salt marsh in this way, with the ability to hear the birds, and explore the habitat as if you were standing there, impacts students for a very low cost. We suggest using the Google Cardboard virtual reality viewers, and cell phones (or iPod touches) that schools or students may already have to view the content.

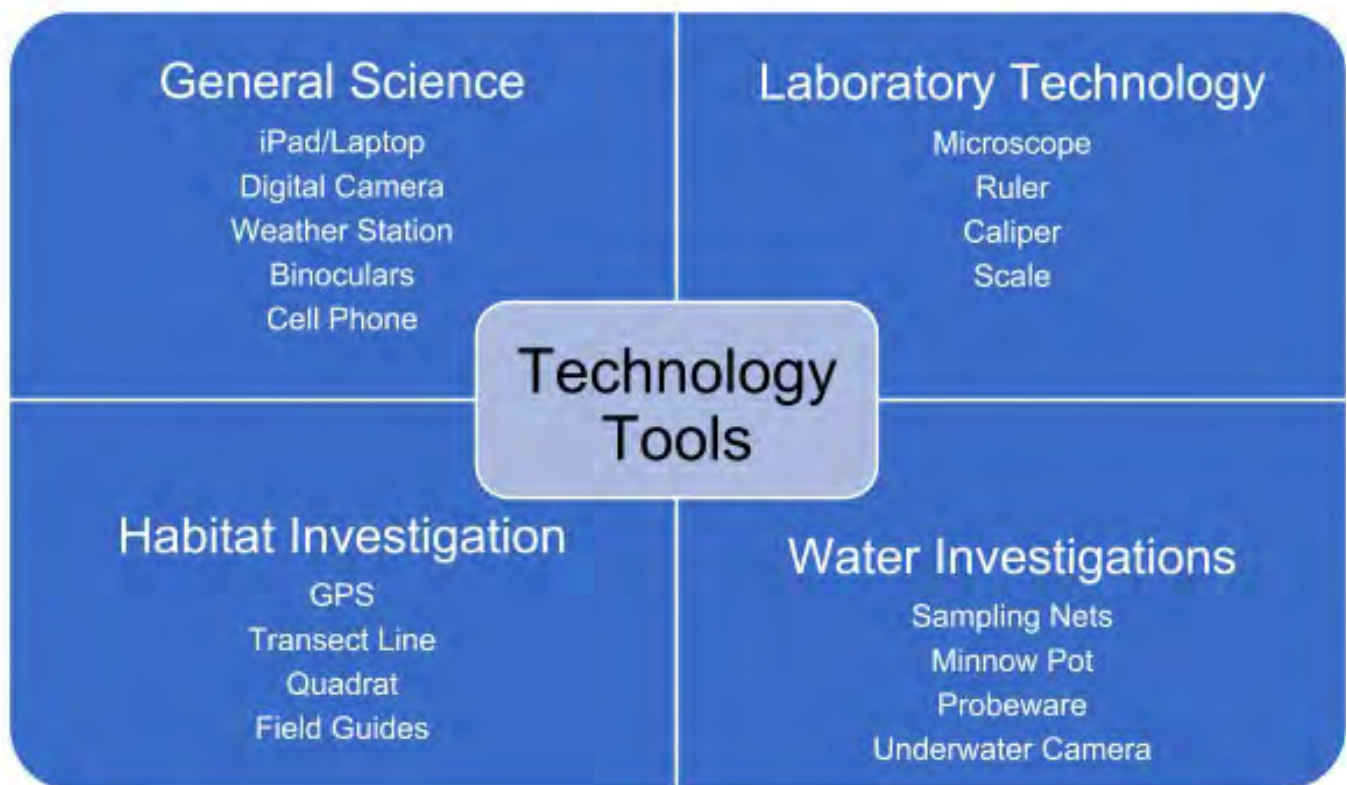


Figure 4: Example of technology used by CBNERR educators

Action Phase Technology

During the action phase of a MWEE, students conduct field science investigations, just as a scientist would. Students participate in one or more outdoor experiences where they make observations, collect and analyze data, and participate in restoration projects to better their local environment. Technology is an easy fit during the action phase, and is typically used to capture both qualitative (images, sounds, interviews of experts in the field, etc) and quantitative (measurements, distances, time, etc) data.

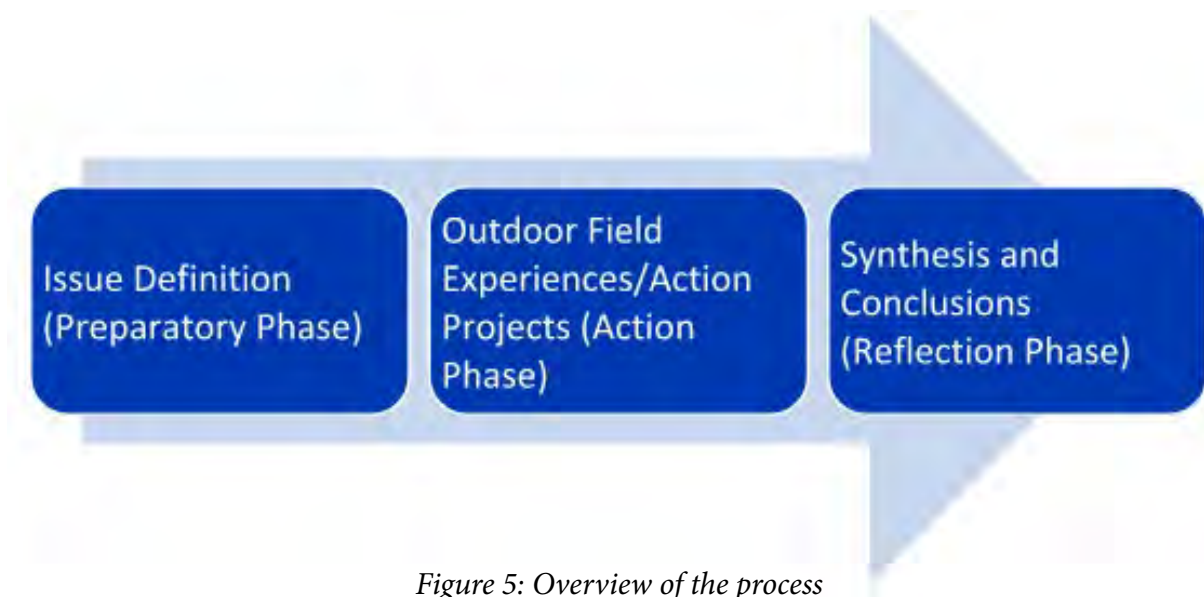


Figure 5: Overview of the process

Throughout the Virginia SOLs, there are several key references to technology to support science investigations. Field experiences at the Reserve typically focus on the SOLs that coincide with our own mission, including:

- 4.6 The student will investigate and understand how weather conditions and phenomena occur and can be predicted. Key concepts include use of weather measurements and weather phenomena to make weather predictions.
- 6.7 The student will investigate and understand the natural processes and human interactions that affect watershed systems. Key concepts include water monitoring and analysis using field equipment including hand-held technology.
- LS.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, and probeware are used to gather data.

Water quality testing is likely the most common type of field investigation conducted by teachers in Virginia. However, the collection, analysis, and sharing of this data needs to be highly structured, and requires background preparation. Time should be allotted to prepare students to use the equipment and parameters prior to time in the field. Students may be new to reading graphs, creating data tables and graphs, or analyzing data. A good first step is the National Oceanic and Atmospheric Administration

(NOAA) Data in the Classroom website (<https://dataintheclassroom.noaa.gov/>). The Water Quality module steps students, and teachers, through the basics of reading one parameter in graphical format, understanding how different water quality factors influence each other, and finally ending in creating personalized investigative questions.

As students are more familiar with graphing and the common parameters typically collected in an estuarine setting (pH, temperature, dissolved oxygen, salinity, and turbidity), students can collect their own data in support of their research question. At CBNERR, water quality data is collected using a variety of tools, as well as structured data sheets to keep students on task and organized. (Appendix 1). While we use Pasco probeware (<https://www.pasco.com/GLX>), all field data can be collected with lesser expensive technology such as thermometers, hydrometers, and tablet tests, typically revealing similar results to the more expensive technology.

Finally, it is important to ensure a feeling of purpose with students collecting water quality data. The data must be used to answer their investigative question, which may require repeated water quality testing throughout the year or at various locations. Another way to make data collection more meaningful is to share the data with others, also typical of what scientists would do. We suggest Chesapeake Bay FieldScope, a National Geographic tool (<http://www.fieldscope.org/>), or any other citizen science monitoring project, such as World Water Monitoring Day (<http://www.worldwatermonitoringday.org/>), to submit data collected by the students for use and comparison by others. Advanced students may also benefit from comparing their data to that collected by scientists or to data from other locations, using websites such as (www.vecos.org, <https://coast.noaa.gov/swmp/>, and <https://buoybay.noaa.gov>). Several of these websites also contain curriculum that accompany the data.

Technology for Reflection Phase

In the reflection phase, students refocus on the question, problem or issue; analyze the conclusions reached; evaluate the results; and assess the activity and student learning. Reflective thinking is part of the critical thinking process, specifically the process of analyzing and making judgments about what has happened (Lin, Hmelo, Kinzer, & Secules, 1999). Through reflective thinking, learners may assess what they know, what they need to know and how to bridge the gap. Using the research by Lin et al. (1999), the University of



Figure 6: Students reflect on their findings

Hawaii produced a Reflective Thinking document which states the importance of reflective thinking in middle school students as being particularly valuable as it can support them in their transition between childhood and adulthood (<http://www.hawaii.edu/intlrel/pols382/Reflective%20Thinking%20-%20UH/reflection.html>). Reflective thinking can provide middle school students with the skills to mentally process learning experiences, identify what they learned, modify their understanding of the topic based on new information and experiences and transfer their learning to other situations. Warner, Eames, and Irving (2014) suggest that social media may be the best venue for this reflection, in order to allow for the continuation from learning about the environment and having positive attitudes about the environment, to taking action, which is something that CBNERR also strives to promote.

To support reflective thinking on CBNERR field experiences, students complete a number of different activities based on age group. For example, elementary students studying the salt marsh complete a mural of the habitat studies, with each student responsible for one animal or plant on the mural. (Figure 7) Students write one fact that they learned on the inside of the image, and one thing they enjoyed about the experience on the outside edge of the image, and then add to the full mural. Murals are displayed at the school to share with other students. In another example of reflection products, high school students present their findings on sea level rise impacts to their community both to their classmates and potentially to local stakeholders.

For some students, technology can be used specifically in their reflection phase. Technology allows students to focus on actions post-field experience, which may not happen otherwise (Agyeman, 2006). For example, students can present their findings of a year-long MWEE regarding the Chesapeake Bay's health and how to help through social media. Twitter provides a platform for each student to create a concise message of what they have learned and how they plan to help the Bay. *Figure 8* Students can even tag many federal and state agencies, local non-profits, and even their local representatives to draw attention to the issues (and solutions) to help the Chesapeake Bay.



Figure 7: Students make a mural based off their findings



Figure 8: Student prepare Tweets

Students use a common hashtag in order to track the messages, and CBNERR educators create a Storify (www.storify.com) of images, tweets, and background information about the entire process. An example from 2013 can be found here: <https://storify.com/cbnerr/queens-lake-bwet-twitter>.

The results from participation in this program can be seen in their post-assessment. Of the seven schools participating in the same program in 2013, this school was the only school to do this type of reflection, and was also in the top three for the highest average post-assessment score. They also had the greatest percent increase of all the schools at 58% between pre and post-assessments. Giving the students time to reflect on the MWEE allowed for very powerful responses, even encouraging teachers and administration to look for funding to continue this project. One 7th grade student wrote,

Yes, I definitely feel that other students should have the opportunity to participate in this program. I really liked it, because we are learning about the Bay, not just in our classroom, but in real life, hands-on, experiencing it. I think that this program could also make more people more interested in/worried about protecting the environment, and especially the Bay (which is something I am very passionate about). Plus it was a lot of fun!

Best Practices

The examples described above show different options for integrating technology into the phases of a MWEE. It is also likely that common technology, such as digital photography, mobile devices, apps, webcams, GPS, and probeware, can support field investigations, no matter the location or topic. For more ideas on technology options, review Technology for Field Investigations: Scientist-Driven Technology Practices (http://www.fishwildlife.org/files/Technology_for_Field_Investigations-CE_Strategy.pdf), a product of the Association of Fish and Wildlife Agencies' North American Conservation Education Strategy.

Lastly, remember that technology should directly support your learning goals, and should only be used if it is adding to your program in some way, either through efficiency or by completing a task that could not be done another way. In summary, our best practices for technology integration for field investigations are:

- Start small
- Practice makes perfect
- Each student has a role,

continued

- A student “reporter” role can document your MWEE for future sharing
- Check out the options along the budget spectrum
- Technology can be used to differentiate
- Select your learning goals first, and your technology last
- Have fun

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