Exploring Techniques for Integrating Mobile Technology into Field-Based Environmental Education

Carrie L. Anderson
University of Idaho, USA

Brant G. Miller
University of Idaho, USA

Karla Bradley Eitel
University of Idaho, USA

George Veletsianos
Royal Roads University, Canada

Jan U.H. Eitel
University of Idaho, USA

Robert J. Hougham
University of Wisconsin-Extension, USA

Abstract

Environmental education authors have argued for cultivating a relationship with nature and the outdoors, and have urged parents to “unplug” their children from technology. In this perspective, technology is seen as curtailing ties to the environment and its use needs to be limited. In this paper, we consider the idea that while technology may contribute to children’s disconnect from the natural world around them, it could also support being outdoors. Thus, we explore techniques for incorporating mobile technology into a field-based environmental science curriculum and compare two approaches to field-based environmental education: a traditional approach and a traditional-plus technological intervention approach. A mixed methods design was used to evaluate learning outcomes and record observations. Based on comparisons of pre- and post-test scores and common themes detected through reflexive journaling, results show that the traditional-plus approach to environmental education facilitated an increase in student knowledge and comprehension during a weeklong residential science program. Appropriate implementation of technology can enable outdoor educators to enhance existing practice, but there is still a need for further research on the topic.

Please address all correspondence to: Carrie L. Anderson, 1800 University Lane, McCall, ID 83638, canderson@naturebridge.org

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Introduction

Many people consider nature to be sacred, peaceful, and pure, and view time spent outdoors as enabling freedom, creativity, exploration, and a physical separation from the hustle and bustle of everyday life (Arrandale, 2006; Pohl, 2006). To venture into nature facilitates reconciliation between humanity and the environment. This relationship is as old as humanity itself, but will this relationship perpetuate into the future given the fast paced, technologically advanced, media-driven lifestyle that is currently prominent in the Western industrialized world?

The developed world is facing a serious disconnect between the next generation of children and the environment (Charles, 2009; Hiller, 2008; Louv, 2005; Rideout, Roberts, & Foehr, 2005; Sobel 1996). Hiller (2008) explains that "new technologies offer children an increasing array of entertainment options that involve staying indoors and being sedentary" (p. 61). Rideout et al. (2005) express similar views by noting that the amount of time children spend being exposed to media (e.g., television, DVDs, video games, computers, and music) is roughly four hours a day – the weekly equivalent of a part-time job. Louv (2005) and Sobel (1996) have written on the challenges of what they term "nature deficit disorder" and "ecophobia." Their writings suggest that a relationship with nature, time outside, and less time with technology, can have positive outcomes for children's mental and physical health as well as help them to develop a caring ethic and concern for conserving the places where they live.

At the same time, other scholars highlight the benefits of technology. For example, Peffer, Bodzin, and Smith (2013) describe how technology can connect children and adults to global issues and promote education related to complex and abstract concepts. Digitally-mediated practices, such as podcasting, remote monitoring, digital recording, and videoconferencing, can lead to engagement with real-world data and the ability to overcome "geographic, cultural, and emotional barriers to learning through authentic investigations" (Peffer et al., 2013, p. 20). Technology can facilitate an increase in personal inquiry and critical thinking through ease of access to information related to scientific questions and observations (Chew-Hung et al., 2012; Evagorou, Avraamidou, & Vrasidas, 2008; Peffer et al., 2013; Vrasidas, Zembylas, Evagorou, Avaraamidou, & Aravi, 2007). In addition, technology, coupled with inquiry-driven and student-centered pedagogies, provides opportunities for relevant, meaningful, and distributed learning experiences (Kurti, Spikol, & Milrad, 2008; Veletsianos, 2010, 2011, 2012).

The drawbacks and benefits of technology lead us to ask: Is technology inherently positive or negative? Or, could the appropriate and meaningful use of technology be part of the solution to reconnecting children with the environment? Should adults put strict all-encompassing limits on children's technology use? Or can intentional engagement with technology prepare children to engage thoughtfully and critically with technology? Incorporation of technology into learning experiences is currently considered the norm in K-12 classroom settings. However, place-based environmental education (EE) and computers have traditionally been seen as adversaries (Hiller, 2008; Louv, 2005; Rideout et al., 2005; Sobel 1996). EE practitioners are just beginning to explore approaches to field-based environmental education that capitalize on the opportunities that mobile technology and devices (e.g., tablets, data loggers, digital cameras, and measurement devices) offer for enhancing learning experiences (Coulter, 2008; Evagorou et al., 2008; Hungerford, Peyton, & Wilke, 1980; Peffer et al., 2013; Vrasidas et al., 2007). The integration of mobile devices in outdoor, place-based environmental curriculum, when compared to a more traditional environmental curriculum, is increasingly necessary to compete for students' attention and can make learning experiences more meaningful and memorable (Evagorou et al., 2008; Hungerford et al., 1980; Peffer et al., 2013).

Mobile Devices in Education

Various studies have explored the use of mobile technology in classrooms and indoor learning environments (Dumont, 1996; Evagorou et al., 2008; Murray & Olcese, 2011). In a classroom setting, tablet computers and personal digital assistants (PDA's) typically serve as a means to connect to the Internet and collaborate with others. Various applications (apps) allow students to connect to cloud computing services and enable easy and efficient file sharing (Murray & Olcese, 2011), while other apps enable students to stay on top of their school work by organizing assignments, deadlines, and tests (Novello, 2012). Apps are also used to create content (e.g., via word processing and video-creating tools) or consume content (e.g., via lectures, reference materials, and other sources such as newspapers). Interactive web-based assessment tools are also available that provide instantaneous feedback for educators related to understanding and retention of content (Dumont, 1996; Novello, 2012).

Many classroom-tested methods and techniques for utilizing mobile technology have been shown to be effective in outdoor learning environments (Evagorou et al., 2008; Hung, Lin, & Hwang, 2010; Kurti et al., 2008; Liu, Tan, & Chu, 2009; Peffer et al., 2013; Ruchter, Klar, & Gieger, 2010; Uzunbylu, Cavus, & Ercag, 2009; Vrasidas et al., 2007). Mobile devices have been utilized in a variety of EE settings, such as self-guided nature walks, outdoor classrooms, field experiments, ecological reflection, and scientific inquiry (Cantrell & Knudson, 2006; Chew-Hung et al., 2012; Hung et al., 2010; Liu et al., 2009; Peffer et al., 2013; Ruchter et al., 2010; Uzunbylu et al., 2009). For example, while engaging in scientific inquiry, students can access field guides or answers to pressing questions related to field observations. Cantrell and Knudson (2006) investigated the use of mobile technology for enhancing scientific inquiry in outdoor education using pocket personal computers and a wireless local area network (LAN) to collect and store data. Students used the wireless network to collaborate and upload data to a central location. Through post-surveys and observations, these researchers reported that over half of the participants had positive attitudes about using technology in an outdoor educational setting and as a tool for collecting scientific data. Others felt that technology interfered with the inquiry process and personal ecological observations.

Personal digital assistants, or PDA's, have demonstrated to be an effective tool to access web-based outdoor educational activities (Cantrell & Knudson, 2006; Chew-Hung et al., 2012; Murray & Olcese, 2011; Uzunboylu et al., 2009), facilitate assessments during outdoor excursions (Hung et al. 2010), and serve as a means for enhancing and broadcasting ecological reflection (Liu et al., 2009). These studies suggest that mobile technology promotes and enhances student observation, collaboration and interaction when compared to traditional forms of instruction, and thus provides a means for accessing, investigating, and sharing environmental concerns through media without being limited by place and time (Cantrell & Knudson, 2006; Chew-Hung et al., 2012; Evagorou et al., 2008; Hung et al., 2010; Liu et al., 2009; Murray & Olcese, 2011; Uzunboylu et al., 2009; Vrasidas et al., 2008). Furthermore, Ruchter et al. (2010) observed that the use of PDA's, now referred to as mobile devices, and other mobile technologies, led to a greater level of engagement in EE activities and an increase in long-term environmental knowledge retention among children.

While some students and educators find that mobile technology positively affects their learning experience (Chew-Hung et al., 2012; Hiller, 2008; Hung et al., 2010; Kurti et al., 2008; Liu et al., 2009; Peffer et al., 2013; Ruchter et al., 2010; Uzunbylu et al., 2009) others report negative attitudes toward the incorporation of technology into field-based EE (Cantrell & Knudson, 2006; Kaplan, 1995; Louv, 2005; Peffer et al., 2013; Pohl, 2006; Sobel, 1996; Sutton, 2011; Vrasidas et al., 2007). As a result, many educators remain skeptical of the integration of technology in field-based EE (Cantrell & Knudson, 2006; Peffer et al., 2013). Some of this skepticism may be based in a philosophical tension associated with bringing technology into the outdoors. With technology comes stress due to connecting with obligations and relationships outside of the frame of the environment, a place that has traditionally been seen as restorative in part because of the absence of such technological tools (Kaplan, 1995; Pohl, 2006). Another source of skepticism is the lack of knowledge on how to appropriately integrate technology into settings that have traditionally been devoid of technology (Sutton, 2011; Vrasidas et al., 2007). Few educators have had training for how to integrate emerging technologies in outdoor settings (Peffer et al., 2013; Sutton, 2011), and even fewer can say that they have themselves been exposed to mobile technologies as a student.

Purpose

This study was designed to address the tension associated with technology and the integration of mobile devices in an outdoor classroom. The objectives for the study were: 1) to describe, implement, and reflect upon a variety of techniques for incorporating mobile technology into a field-based environmental science curriculum, and 2) to compare differences in understanding and comprehension of ecological content between a traditional approach to environmental education and a traditional-plus technological intervention approach to environmental education, within a K-12 outdoor learning environment. By investigating changes in learning outcomes, this study addressed the potential fear that technology can distract from learning and discourage a connection with the natural world. The guiding research questions were:

1. What are potential techniques for incorporating mobile technology into a field-based environmental science curriculum that will benefit student learning outcomes?

2. Do learning outcomes differ between a traditional and traditional-plus technological intervention approach to teaching a field-based environmental science curriculum?

Study Context

This study was conducted in the fall of 2012 through fall 2013 at the Ponderosa Science School (PSS) (pseudonym). PSS was founded in 2001 as a field campus of a mid-size northwestern university and is currently a publicly operated K-12 residential outdoor science school. The mission of PSS is to facilitate place-based, collaborative science inquiry within the context of the state's land, water and communities. PSS provides experiential learning opportunities among students, educators, scientists, and citizens to foster the critical thinking skills necessary to address complex problems. Outdoor field based activities and hands-on educational experiences are crucial components of all PSS curricula and the "classroom" is the local state park, which is adjacent to the campus. To fulfill its educational goals, PSS annually supports up to 20 graduate students who are pursuing degrees in natural resources or education and are completing the requirements for a graduate certificate in environmental education. These graduate students serve as the field instructors for the PSS's residential science programs and summer experiences.

Typically, upon arrival at PSS for a residential science program, the participating school is divided into field groups consisting of one or two graduate field instructors, 5 – 10 students, and at least one adult chaperone (Table 1 describes a typical 5-day youth residential program). Prior to the arrival of a school at PSS, the teachers have the option to select up to two of four field-based learning modules to be covered during the content days of the program: *Go with the Flow*, *Geology Rocks!*, *Awesome Adaptations!*, and *Exploring Ecosystems*. All schools participating in this study selected *Go with the Flow* as one of their learning modules. The *Go with the Flow* module discusses the hydrology of the local landscape, which includes an in-depth description of the water cycle and local watersheds, and testing and comparing the water characteristics of at least two water sources (e.g., water temperature, pH, dissolved oxygen content).

Table 1. *Description of a typical 5-day youth residential program at the Ponderosa Science School (2012)*

Day #	Program description
1	Arrival, orientation, team building, and development of group contracts
2	Content day
3	Content day
4	Student-led inquiry day
5	Presentation of student inquiry projects and departure

Participants in this study received the *Go With the Flow* curriculum through a traditional approach to environmental education, or a traditional approach plus a technological intervention. Specifically, two of the four participating schools received a traditional approach to teaching the *Go With the Flow* learning module, constituting the control group that was made up of 17 students. The remaining two schools received the traditional approach plus the technological intervention described below, constituting the treatment group that was made up of 14 students.

Traditional Approach

The traditional approach to environmental education deemphasized the use of mobile technology (tablets, mobile data loggers, and digital cameras) during the *Go with the Flow* learning module. The students had no direct contact with the tablets and access to the Internet, via wireless connectivity, was limited to the PSS campus. At the start of the traditional approach to the *Go with the Flow* module, a hand drawn concept map was shown to the students to introduce the events of the day (Figure 1a). This map was a visual representation of the activities and concepts to be covered, the locations to be visited during the field day, and other necessary information (e.g., snack time, lunch time, and bathroom breaks).

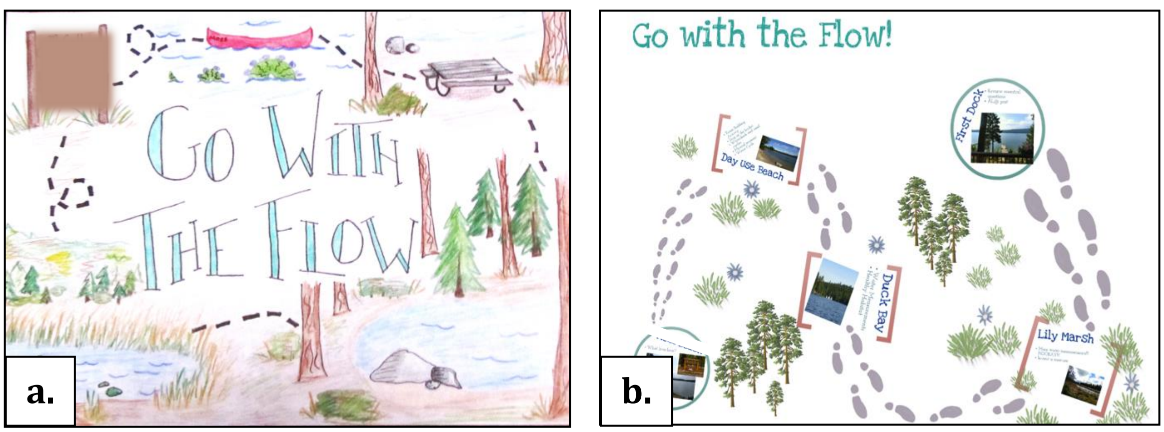

Figure 1. a) Hand-drawn mind map, incorporated into the traditional hydrology curriculum. b) Digital mind map, incorporated into the technology-plus technological intervention hydrology curriculum, created using the storytelling software package Prezi (http://prezi.com) and displayed in the field using a tablet.

Basic concepts were introduced and elaborated on through the use of traditional environmental education techniques and printed resources including: field guides, fact sheets, visual aids, and paper maps. Explanation of the water cycle was conducted using a printed and laminated visual aid depicting the cycle through images and drawings and field instructor led activities, games and songs. The concepts of watersheds and watershed addresses (i.e., the names of different bodies of water within the watershed between the headwaters and the ocean) were introduced using hands-on mapping activities (e.g., sand castles and topographic maps) and then further investigated by tracing an entire watershed from source to sea on paper using laminated maps and dry erase markers.

All field groups were required to post field updates to the program website and blog as part of the goals and mission of PSS. Blog posts can then be viewed through the program website and commented on by parents, teachers, and fellow students. This website and blog is an extension of the adventure learning approach. Adventure learning is an educational pedagogy that connects students to real-world experiences, professionals, and cultures in remote locations through a hybrid online learning environment and authentic learning opportunities (Doering, 2006). One of the main goals of this approach is to empower students and teachers to share their authentic place-based inquiries using technology (Hougham, Eitel & Miller, 2012; Miller, Hougham, & Eitel, 2013). In the traditional approach, the students were given the opportunity to reflect upon their experiences and record their thoughts in their personal journals. The students then dictated excerpts from these journals to the graduate field instructor (who was in control of the tablet) to be uploaded to the program website and blog in the form of field updates and reflective blog posts upon returning to campus. Students in the control group hand recorded all of their scientific data describing the characteristics of local bodies of water, which were later transcribed and uploaded to an online database by the field instructor that allowed for the storage, access, and publication of hydrologic data. These data were then made publicly available. The dictation of updates and transcription of data by field instructors limited the student's exposure to technology to a minimum.

The traditional group was also limited in their access to the use of the mobile data loggers and electronic measurement instruments and probes. Hydrologic data collection was conducted with low-tech measurement tools such as pH strips, turbidity tubes, and qualitative observations that evaluated presence and absence of aquatic organisms, oily sheens, etc. To investigate less tangible water characteristics such as conductivity and dissolved oxygen content, students had minimal use of digital measurement probes and the field instructor mediated the use of these instruments.

Traditional Approach Plus Technological Intervention

The traditional-plus approach to field-based environmental education included all instructional and facilitation techniques utilized in the traditional approach, plus the incorporation of mobile devices (tablets, mobile data loggers, and digital cameras) and wireless connectivity while in the field. Students in the traditional-plus group had monitored access to the group's tablet (after an explanation of proper tablet use from the field instructor). Available apps on the tablet included the camera, video recorder, calculator, and notes. In addition, an app associated with the program web environment enabled students to capture and upload their ecological observations, descriptions and narratives of their experiences, and student driven scientific inquiries while in the field.

At the start of the traditional-plus technological intervention approach to the *Go with the Flow* module, a digital concept map (created using the storytelling software package Prezi: http://prezi.com) was shown to the students on the tablet to introduce the events of the day (Figure 1b), in contrast to the hand drawn concept map utilized in the traditional approach. Basic concepts were introduced and further investigated with the aid of online resources via the tablet. An explanation of the water cycle was conducted using a combination of publicly available online videos and instructor-led activities and songs.

The concept of watersheds and watershed addresses were introduced using the same hands-on mapping activities (e.g., sand castles and topographic maps) as the traditional approach, and then further investigated by tracing an entire watershed from source to sea using Google Earth (earth.google.com) and the "Surf Your Watershed" website developed by the Environmental Protection Agency (http://cfpub.epa.gov/surf/locate/index.cfm).

Students in the traditional-plus group had direct contact with the tablet to create their own blog posts, complete with photos and videos, and uploaded those posts to the program website and blog from the field. Upon completion of data collection related to the characteristics of local bodies of water, students in the traditional-plus group uploaded their scientific data to the online database using the tablet and wireless connectivity. The traditional-plus group had unlimited access to the use of the mobile data loggers and electronic measurement instruments and probes throughout the hydrology content day.

Methods

A mixed methods design was chosen to address the following research questions: 1) what are potential techniques for incorporating mobile technology into a field-based environmental science curriculum that benefit student-learning outcomes? And 2) do learning outcomes differ between a traditional and traditional-plus technological intervention approach to teaching a field-based environmental science curriculum? Both quantitative and qualitative data were collected to examine variables related to technology integration and to reflect upon the successes and failures associated with different techniques for incorporating technology into a field-based environmental science curriculum. The mixed methods design balances the strengths and weaknesses of both qualitative and quantitative data to paint a more representative picture of the educational experiences and learning outcomes observed in the field (Lederman & Lederman, 2013).

Quantitative Data

Collection. The quantitative data collection component of this study addresses the second research question presented in this study: do learning outcomes differ between a traditional and traditional-plus technological intervention approach to teaching a field-based environmental science curriculum? The quantitative data were collected as exploratory action research (Carr & Kemmis, 1986; Capobianco, 2007; Sagor, 2011) in the fall of 2012 and spring of 2013. This action research design was selected to better inform the practice of the lead author. The lead author was a field instructor at PSS during the time of the study and responsible for using technology while facilitating environmental education activities as part of the mission of PSS.

A total of 31 students (16 male and 15 female) from four schools located at a medium sized city in the western United States participated in the quantitative part of this study. The sample population included 4th - 6th grade students from a variety of social and economic backgrounds that were attending a three to five day youth residential science education program at PSS. All students participated in the same content day at PSS: *Go With the Flow*.

Pre- and post-surveys.

Content-specific pre-tests (Appendix A) and post-tests (Appendix B) were administered to both the traditional (14 students), and the traditional-plus (17 students) groups. These assessments were administered at the start and end of the *Go With the Flow* content day and directed students to state their level of familiarity with terms and concepts associated with hydrology. If the student felt that they had a strong understanding of the term, they were asked to define it to the best of their ability. Each student's answers on the pre- and post-tests were evaluated on a scale of 1 to 4 based on the level of familiarity with the terms and concepts that each student expressed (Table 2).

Table 2. *The point value system used to evaluate the student's responses on the pre- and post-tests for the traditional group and the traditional-plus group*

Response category	Point value
I've never heard of this before	1
I've heard of this but don't know what it is	2
I've heard of this and think it means/is…	3
My answer or definition	4

Analysis. Pre- and post-test scores were analyzed to determine changes in familiarity and understanding of relevant science content vocabulary before and after the *Go with the Flow* module. The Kruskal-Wallis Test for non-parametric variables was used to show the magnitude of change between pre- and post-test responses for both the traditional and traditional-plus student groups. Given the small sample size for this study, additional, more sophisticated data analysis was not appropriate. Thus, descriptive statistics were also employed to illuminate the nature of student responses as a result of experiencing the traditional-plus approach and its affects on student learning.

Qualitative Data

Collection

The qualitative data collection phase of the study complements and adds depth to the findings of the quantitative component. The lead author kept a reflexive journal for the duration of the qualitative component of the study (Cunliffe, 2004; Glaser & Strauss, 1967). This journal recorded daily descriptions and observations of all technological interventions used to teach lessons and facilitate learning experiences. These observations were related to the implementation of the interventions that were examined during the quantitative phase of the study. In addition to descriptions and observations, the journal also included reflections on successes and failures related to those interventions and resulting learning experiences.

A total of 20 observations and journal entries were collected during the duration of the qualitative component, which lasted 12 weeks. Qualitative data were collected after the completion of the quantitative component of the study from a separate sample population (32 students; 4th – 5th grade; 14 male and 18 female) that did not include the 31 students that participated in the quantitative part of the study. The qualitative data informed the following research question: What are potential techniques for incorporating mobile technology into a field-based environmental science curriculum that benefit student-learning outcomes?

Analysis. The data (i.e. the journal entries) were analyzed by examining repeated vocabulary and commonalities between the different groups. In particular, the lead author read and examined each individual journal entry, and analyzed each entry independently and in comparison to each other. The lead author coded the entries in an open manner in an attempt to answer the posed research question. This process allowed the lead author to conduct an iterative and comparative analysis (Charmaz, 2011). Once all entries were read, the codes were compiled and summarized to arrive at two themes that are described below. Representative excerpts from the journal are shared below. The lead author's journal entries were supplemented by quotes from student blog entries to illustrate specific examples referenced in the lead author's observations and descriptions.

Results

Quantitative Data

The following results were identified based on the findings from pre- and post-tests. The pre- and post-test scores were compared between the traditional and the traditional-plus student groups. Figure 2 shows the difference between pre- and post-test scores for all participants in this study. The post-test scores indicated a greater frequency of students defining answers to questions based on their experience in the traditional-plus groups. This indicates that the impact of the traditional-plus treatment on student learning was in the direction of supporting learning outcomes in students.

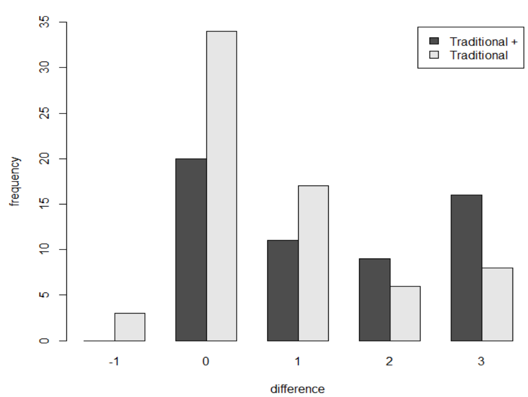

Figure 2. Difference in students' pre and post scores of all combined questions grouped by the treatment traditional and traditional-plus.

Next, pre- and post-test scores were compared within the control and treatment groups to determine if a change occurred in learning outcomes within the two approaches. Table 3 displays the change in student responses pre- to post-test per question using the Kruskal Wallis Test for non-parametric variables. Of the eight questions on the pre/post-test, questions 2-4, and 8 were removed for the analysis because not all students answered them or there was discontinuity in respondents. Results represented in Table 3 indicate gains for both students groups showing that learning happened in both approaches. It is noteworthy that although there was a statistically significant difference in the learning outcomes for both groups on certain questions, overall the magnitude of significance is greater for the traditional-plus group than the traditional group. Thus, having access to technology and using it in the ways described above afforded students greater access to information and subsequent learning outcomes.

Table 3. *Results of the Kruskal-Wallis Test for non-parametric variables.*

Question #	p-value for Traditional	p-value of Traditional +
Question 1	0.06472	0.009828*
Question 5	0.2931	0.08678
Question 6	0.002386	0.0006609
Question 7	0.0006609	0.0002142

*$p < .05$

Qualitative Observations and Common Themes

Two common themes emerged from the analysis of the observations and reflections recorded through reflexive journaling and supportive quotes and examples from student blogs: 1) the students broadcasted their lived experiences at PSS through blogs and field updates, and 2) the use of novel technologies for educational purposes was perceived to lead to positive impacts.

Broadcasting lived experiences. As described above, each field group was required to post field updates to the program website and blog during their content day. Blog posts gave students the opportunity to reflect on the events of the day and share experiences that they found interesting or facts and concepts that they learned. One student described the events of inquiry day (a scientific learning experience) as follows

> Today we went to the water and we canoed to the middle of the lake to measure the water temperature and the dissolved oxygen in the water. And this is how we got out there… 'Stroke, stroke, stroke' Kayla [pseudonym] said deeply as the canoe went faster and faster. 'Lets try it now' George [pseudonym] shouted as we slowly came to a stop. 'Can you see the bottom George?' Ms. Smith [pseudonym] said as she kept going to keep us steady. 'I can see the bottom Ms. Smith' Emily [pseudonym] said as she looked over and glanced into the water. 'Can't measure here, let's keep going then' Ms. Smith said. 'Stroke, stroke, stroke' Kayla shouted repeatedly. As we made white water…

Other students used the tablets to capture photos and videos describing an experience at PSS that they explicitly wanted to show to others, as illustrated in the following journal entry:

> The students carefully recorded and described a scientific experiment in detail, using photos and videos, with the intent that their parents (individuals completely unaware of the situation or methods being used) could understand what they were doing to discover something about the ecology of the region. Through communicating the step-by-step process of collecting and analyzing data, this experience served as a formative assessment of the students' comprehension of concepts being presented. Technology enabled the students to reach out and share their experiences with a broader audience, inspiring a more detailed and in-depth description of their learning experiences.

The opportunity provided to the students to blog about their experiences appeared to motivate them to observe the world around them more closely, explain the steps they were taking to collect and analyze data, and make discoveries that were "worth blogging about" (excerpt from reflexive journal).

Novel technologies perceived to lead to positive educational impacts. Another theme that emerged from the analysis of the qualitative data was that interacting with novel technologies perceived to lead to positive educational impacts on participating students. Many students from both urban and rural communities have had few opportunities to interact with new technologies, like tablets and scientific instruments in an educational context (Kim et al., 2011). At PSS, techniques like using interactive websites related to water resources and measuring/recording the characteristics of local bodies of water enabled students to use novel technologies in a field-based learning experience. Using technology in this way appeared to motivate students and foster unique learning experiences. The following journal entry indicates the lead author's beliefs regarding the potential impact of such experiences:

> Memorable technological experiences inspired confidence in the students' ability to answer questions. They made a mental association between defining and measuring pH with the tablet, which the students used to look up what the letters stood for and how it is measured. Later on, during the school wide review on the last morning of the program, my students were the first to have their hands in the air to answer questions related to pH. After correctly answering the question, Matt [pseudonym] turned to me and said, 'remember… we figured that out with the [tablet]!'

Students also appeared to be able to understand certain concepts much more quickly when instruction was facilitated via technology. For instance, using the EPA's "Surf Your Watershed" interactive website allowed students to explore their local watershed in more detail than a paper map and printed materials can provide. Also, journal observations indicated that the lead author believed that by interacting with digital data and observing interactive simulations students were able to understand that everything happening in a river upstream impacts the water quality downstream, and that this conceptual understanding would traditionally involve a more drawn out process facilitated by the lead author that does not always engage the entire group.

The lead author also noted that using the scientific measuring tools appeared to make the data collection process more exciting and accessible. Collecting data for themselves using mobile technology made conducting scientific research and understanding what each number or measurement means more accessible. Measuring water temperature and dissolved oxygen content using a digital sensor or mobile computer and measuring probe as opposed to using traditional methods like thermometers, colorimetric test kits, and pH strips, seemed to get students excited about the prospect of being scientists:

> The students thought the Vernier Labquests and associated probes were really neat! They even argued at times of who got to use that piece of technology next. [The students] loved seeing something that captured their interest (i.e., the marsh or the lake) in a different way and I think that their interaction with the tech made them feel more like scientists… It was very rewarding seeing the technology used to inspire observation, inquiry, and excitement towards science.

Discussion

In this study, we investigated 1) potential techniques for incorporating mobile technology into field-based environmental education, and 2) how learning outcomes differ between a traditional approach and a traditional approach plus technological intervention. The traditional-plus approach encompassed a new pedagogical method that made use of technological affordances to enable students to investigate hydrology and the water resources of the outdoor classroom. The results showed that compared to a traditional approach to teaching this content, participants assigned to the traditional-plus approach exhibited greater increase in scores between pre- and post-tests. Qualitative observations revealed the enthusiasm surrounding the use of technology in this context and the student desire to share their lived experiences with others. The perceived increased engagement and enthusiasm is consistent with observations recorded by Chang, Chen, and Hsu (2011) and Chew-Hung et al. (2012) during their studies applying technology in field-based educational experiences.

Mobile technologies that were examined in this study included tablet computers, mobile data loggers, and wireless connectivity. Methods for technological integration that were examined in this study were:

- The use of tablet computers to display visual aids, pictures and videos, and access web-based resources.
- The use of tablet computers to record and interact with data, and compose and publish field updates and blog posts.
- The use of mobile data loggers and digital measuring devices to collect and explore ecological characteristics of local bodies of water.

All of these methods were understood to help, not hinder, the learning process during a field-based environmental science curriculum due to their ability to increase observation, communication, and inquiry amongst the students. These findings align with those of Cantrell and Knudson (2006) and Peffer et al. (2006) who found that the integration of technology into field-based curriculum led to greater communication and collaboration related to environmental issues and scientific questions. Technology aided in the students' development of "environmental identity or sense of place" (Peffer et al., 2013, p. 17).

We observed that the traditional-plus approach to environmental education fostered student engagement and motivation towards participation in outdoor EE programs. For instance, the opportunity to use mobile devices served as an incentive to strive towards making thoughtful ecological observations and reflections. In addition, students participating in the traditional-plus approach to EE were able to relate more to the instructional approach employed. This finding is reflective of Kurti et al. (2008) and Ruchter et al. (2010) who found that contact with mobile technology helped to increase student engagement and participation during outdoor learning experiences.

We also hypothesize that student collaboration in the field, first-hand experiences with the data, and review of blog posts made by other field groups and students on the website allowed students to gain a better understanding of the concepts discussed during the experience. Students were exposed to concepts and issues that other students felt were important enough to publish, and access to information published by peers led to increased participation and engagement with the content. Our findings are reflective of those of Uzunboylu et al. (2009) who found that through communication and collaboration via mobile devices, students gained a better understanding of environmental topics and issues.

Finally, the techniques for incorporating technology employed in this study allowed students to explore the ecological interactions present on the landscape on a deeper level than was observed with the traditional approach to EE. Through the use of online tools, such as the EPA's "Surf Your Watershed" and online databases, the participants were able to visualize their location in the watershed and explore connections between the landscape that constituted their current outdoor classroom and the greater ecological landscape located downstream. These technological affordances facilitated critical thinking and application of knowledge to relate local issues to other regions of the globe, similar to the findings of Evagorou et al. (2008) and Vrasidas et al. (2007).

Limitations

There are a number of limitations with this study. The sample size of the quantitative part of the study was limited to 31 students, which limited our ability to conduct statistical analyses and make inferences to the greater population. In addition, in reference to the quantitative part of this study, three of the schools attended PSS in the fall, and the remaining school attended PSS in the spring, producing a chronological gap in the study.

The results suggest that the traditional-plus approach enables students to gain a greater understanding of the content, but our research methods and design do not allow us to attribute changes to particular variables. We observed differences between the two groups, but parsing the nuanced differences in the two approaches was not accounted for in this study. Both the traditional group and the traditional-plus technological intervention group had contact with mobile technologies leading to weak distinctions between the control and treatment groups.

Future research should address these limitations and employ a larger sample size and a design that distinguishes the specific impacts of various technological affordances employed with the traditional approach plus technological intervention. In addition, future research should explore the application of different types of mobile technology in place-based environmental education. Little is known about the potential of digital imaging devices, such as action cameras, life logging cameras, infrared cameras, and wireless digital microscopes, to enhance observation and reflection and inspire scientific inquiry in a field-based educational curriculum.

Summary

This study reveals educational benefits related to enhancing traditional field-based environmental education by rethinking how this content is taught. In contrast to the perspective that students need to be completely unplugged whenever they embark into nature in order to benefit from the experience, technology combined with improved EE teaching techniques can enhance the learning experience of the students rather than degrade it. While many educators remain skeptical of the idea of putting another screen between a student and experiential environmental educational opportunities, mobile technology can have a place in the field of outdoor education and a role in enhancing instruction and investigation. Based on the quantitative and qualitative results of this study, technology when implemented appropriately can allow outdoor educators to enhance existing practice.

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Appendix A

Pre-test that was administered to the traditional group and the traditional-plus group at the start of the *Go With the Flow* content day.

This pre-test will not be graded, please just fill in the answer to the best of your knowledge.

	Term	I've never heard of this before	I've heard of this but don't know what it is	I've heard of this and think it means/is...	My answer or definition
1.	Percentage of earth covered by water				
2.	Greatest amount of water on earth and at what %				
3.	Define: Watershed				
4.	Define: Watershed Address				
5.	Define: Temperature				
6.	Define: Dissolved Oxygen				
7.	Define: Turbidity				
8.	Define: pH				

Appendix B

Post-test that was administered to the traditional group and traditional-plus group at the

This post-test will not be graded, please just fill in the answer to the best of your knowledge.

	Term	I've never heard of this before	I've heard of this but don't know what it is	I've heard of this and think it means/is...	My answer or definition
1.	Percentage of earth covered by water				
2.	Greatest amount of water on earth and at what %				
3.	Define: Watershed				
4.	Define: Watershed Address				
5.	Define: Temperature				
6.	Define: Dissolved Oxygen				
7.	Define: Turbidity				
8.	Define: pH				

	Additional Questions		
9.	Did the use of technology help you learn today?	___ Yes ___ No	Why?___________________________ ____________________________ ____________________________ ____________________________
10.	Would you prefer to have more or less use of technology during the lesson?	___More ___Less ___Fine as is	Why? ___________________________ ____________________________ ____________________________ ____________________________