Integrating iPad Technology in Earth Science K–12 Outreach Courses: Field and Classroom Applications

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ABSTRACT

Incorporating technology into courses is becoming a common practice in universities. However, in the geosciences, it is difficult to find technology that can easily be transferred between classroom- and field-based settings. The iPad is ideally suited to bridge this gap. Here, we fully integrate the iPad as an educational tool into two graduate-level K–12 in-service teacher outreach classes, one classroom-based course and one field-based course. We describe our field and classroom course objectives, and the integration of iPads into both settings. We assess the impact of the iPad in these courses through the use of pre- and posttests and surveys. Most participants enthusiastically use iPads once the initial learning curve is overcome. They tend to spend roughly the same amount of time using technology, but they substitute iPad use for laptop use once they become proficient with the iPad. Additionally, when equipped with an iPad, there is a possible increase in overall productivity as the participants spend more time preparing both for their university outreach classes and the classes they teach. However, they do spend more time on certain noneducational activities (i.e., picture/music/movies), but they appear to be more efficient and spend less time browsing the internet and conducting research for their classes. Interestingly, having participants work with iPads appears to increase confidence in general technology use, including laptops, as well as increasing confidence in the iPad as a teaching tool for their own classrooms. Pre- and posttest data suggest that there is no link to increased content knowledge by integrating iPads versus traditional teaching methods. © *2013 National Association of Geoscience Teachers*. [DOI: 10.5408/12-318.1]

Key words: iPad classroom integration, K–12 outreach, field courses, Earth Science

INTRODUCTION

Over the past decade, Earth Science field- and classroom-based teaching models have successfully adopted new technologies and electronically based scientific visual aids (Hesthammer et al., 2002; Libarkin and Brick, 2002; Kelly and Riggs, 2006; Elkins, 2009). For example, these models often involve PowerPoint presentations, electronic notes and books, internet-based assignments in the classroom, and field data acquisition technology (i.e., laptops coupled with Electronic Total Stations and Global Positioning Systems [GPS]; Brown, 1998; Schlische and Ackermann, 1998). Specifically, this has often been carried out through the use of computers (laptops), but recent technology integration includes Palm Pilots (Guertin, 2006) and iPods (Elkins, 2009). Guertin (2006) cautions that the full extent of electronic device use may be difficult to assess in geoscience classrooms due mainly to uncertainty of instructor use.

The iPad technology (Apple Inc., 2013a) strives to inspire "… creativity and hands-on learning with features you won't find in any other educational tool—on a device that students really want to use. Powerful apps [applications]…let students engage with content in interactive ways, find information in an instant, and access an entire library wherever they go" (Apple Inc., 2013b). iPads are being integrated in pedagogical and learning practices (Manuguerra and Petocz, 2011; Cochrane et al., 2013; Hargis et al., 2013; Keane et al., 2012). However, further study is needed to understand how to best integrate the new iPad technology in both the geoscience classroom and in a field-based setting. Qualitative inquiry methods and theory are becoming important metrics for understanding geoscience educational practices (Feig and Stokes, 2011). There have been significant advances made in understanding that students struggle with grasping spatial relationships. This can be ameliorated by the use of three-dimensional (3D) visualization and computer models, fieldwork in addition to coursework, and experience (Lord, 1985, 1987; Orion et al., 1997; Sorby, 2001; Kastens et al., 2009; Titus and Horsman, 2009; Almquist et al., 2011).

Field-based courses serve as a cornerstone in Earth Science education (Whitmeyer et al., 2009). Field trips are an important part of student learning, conceptual growth, and understanding (Orion and Hofstein, 1994; Elkins and Elkins, 2007). Field courses have been proven to be beneficial to all levels of students, including introductory Earth Science students (Spencer, 1990). Despite the expectation of teaching Earth Science in the K–12 classroom, elementary education majors typically have little or no field or outdoor experiences, and the classes they enroll in do not focus on teaching science content (Cantrell et al., 2003; Dickerson et al., 2007).

Although very beneficial to a range of students, teaching field-based classes can often present significant challenges for a number of reasons. Traditional lecture material and notes are cumbersome and often impractical in a field-based setting. To transfer information and data into the field and classroom, paper-based handouts, posters, and maps have traditionally been utilized. Aside from problems associated with the logistics of creating these materials, several other issues arise due to degradation through exposure to the

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elements, static representation of images on paper, and the inability to alter and/or display different aspects of data sets in the field. These factors have been driving the Earth Science community towards exploring technology for field applications (Clegg et al., 2006; De Donatis and Bruciatelli, 2006; Manone et al., 2006; Goldup, 2013).

This study presents several field and classroom uses of iPad technology in graduate-level K–12 outreach courses and measures the students' attitudes, perceived impact, and content-knowledge growth associated with fully integrating iPads in these settings.

EARTH SCIENCE OUTREACH CLASSES AT RICE UNIVERSITY

For several years, the Rice University Department of Earth Science has led an outreach initiative composed of teaching a suite of classroom- and field-based Earth Science courses to K–12 in-service educators. The classroom participants consist of teachers taking these courses for graduate credit, and they often take a full suite of the courses over several years. Recently, the use of iPad technology has been incorporated into our curriculum during a summer field-based course followed by an academic classroom semester-long course. Therefore, this group of course participants (defined here as university graduate students who are also K–12 educators) allowed us to develop specific field and classroom uses for iPad technology in university geoscience outreach courses.

FIELD AND CLASSROOM COURSE OBJECTIVES

Field Course Objectives

From July 18 to 28, 2011, twenty K–12 science teachers participated in a field-based course (ESCI 515). The reported demographics include 10% African American participants, 20% Hispanic participants, and 70% Caucasian participants with an average age range between 43 and 52 y. The course goals were to: (1) work in small groups designed to foster scientific independence and collaboration, (2) gain familiarity and mastery of scientific technology (ground penetrating radar, sediment coring, GPS handheld units), (3) interpret scientific data in a historical context, (4) acquire field and laboratory experience, and (5) ultimately share this experience with their own students. Specifically, the course focused on a geologic and oceanographic investigation of Galveston Island, Texas. The examination included investigating hurricane events, evaluating shoreline and bayline erosion, understanding nearshore physical oceanography, differentiating coastal environments, and assessing natural and anthropogenic impacts. Participants of the course were required to develop and conduct scientific research projects in small groups that could be completed within the time frame of the course. Example projects (see supplemental file for Field Course Projects; available at: http://dx.doi.org/10.5408/12-318s1) include the following topics: (1) the influence of a seawall's edge on accelerated erosion, (2) examining the short-term impacts of Hurricane Ike (2008), (3) assessing the differences between natural and artificial dunes, and (4) investigating a prograding beach ridge complex. With support from instructors, participants had access to a range of tools and data sets to undertake these projects.

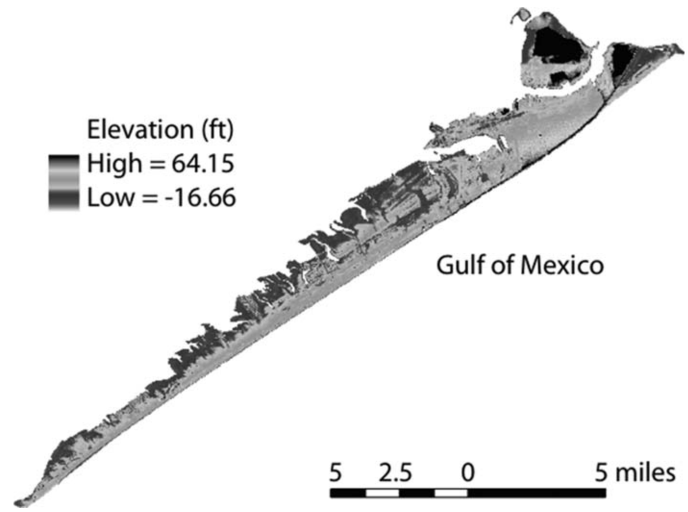

FIGURE 1: LIDAR elevation data set of Galveston Island (located along the upper Texas coast) distributed to participants.

Field Data and Tools

Light Detection and Ranging (LIDAR) Data

A high-resolution elevation data set for Galveston Island was available to participants (Fig. 1). Participants were able to identify coastal geomorphic features on Galveston Island, such as beach ridge and swale topography, washover channels, and dunes. Participants had access to the data while in the field on their iPads. They were able to roughly locate themselves with respect to satellite-based data using the iPad-assisted GPS. This information could then be analyzed in the field and in the laboratory setting using geographic software on iPads (Table I) and computers (ArcGIS).

Sediment Coring

Participants were able to collect shallow sediment cores (Fig. 2) from a number of locations. An AMS, Inc., sand sludge sediment probe was used, designed to collect and recover 2 ft (0.6 m) sections of dry sand. We successfully reoccupied the same hole to couple these 2 ft sections to a total core depth of 6 ft (1.8 m). Each section took roughly 15 min to collect. Cores were opened lengthwise, described, and sampled by participants. Cores were photographed by participants using their iPad built-in camera. The sampling was intended to examine variations in grain size, organic material, macroscopic mollusc shell abundances, and mineralogy. These cores were then wrapped in cellophane and taken by participants to discuss in their classrooms.

Ground Penetrating Radar (GPR)

Ground penetrating radar data were collected for/by participants in an effort to image the shallow subsurface below Galveston Island. Due to the low elevation of the barrier and thus the relatively high saltwater table, the subsurface was only minimally imaged. Despite the limited data acquisition, all participants spent some time collecting data, to see the process and timing involved.

TABLE I: Compilation showing the apps provided specifically for our two courses (some were free; others were purchased for the participants) in addition to apps suggested to participants for additional information. The specific course uses for all apps in ESCI 511 and 515 are noted.

App Name	Course Uses	Link
Provided for Course		
ArcGIS	Map image/elevation data visualization	http://itunes.apple.com/us/app/arcgis/id379687930?mt=8
Dropbox	Sharing files, submitting assignments	http://itunes.apple.com/us/app/dropbox/id327630330?mt=8
iMovie	Record/edit videos	http://itunes.apple.com/us/app/imovie/id377298193?mt=8
Keynote	View/create presentations	http://www.apple.com/iwork/keynote/
Notes	Field/course notetaking	http://www.apple.com/ipad/built-in-apps/
Numbers	Spreadsheet creation	http://www.apple.com/iwork/numbers/
Pages	Word processing	http://www.apple.com/iwork/pages/
ReelDirector	Record/edit videos	http://itunes.apple.com/us/app/reeldirector/id334366844?mt=8
Suggested for Additional Information		
EarthObserver	Elevation, bathymetry, and geologic data	http://itunes.apple.com/us/app/earthobserver/id405514799?mt=8
Geograph TX	Texas geologic map data	http://itunes.apple.com/us/app/geograph-tx/id323930546?mt=8
geotimescale	Geologic timescale	http://itunes.apple.com/us/app/geotimescale/id327090162?mt=8
Google earth	Map image visualization	http://itunes.apple.com/us/app/google-earth/id293622097?mt=8
iBooks	Download/read books and PDFs	http://itunes.apple.com/us/app/ibooks/id364709193?mt=8
iSeismometer	Detect ground motion	http://itunes.apple.com/us/app/iseismometer/id304190739?mt=8
NASA App	NASA data and information	http://itunes.apple.com/us/app/nasa-app/id334325516?mt=8
Rocks & Gems	Rock and gem references/definitions	http://itunes.apple.com/us/app/rocks-gems/id351060567?mt=8
Topos2Go	Download and view topographic maps	http://itunes.apple.com/us/app/topos2go/id307752385?mt=8
USGSSeismic	Recent global earthquake data	http://itunes.apple.com/us/app/usgsseismic/id333208233?mt=8

FIGURE 2: (A) Students had the ability to collect shallow sediment cores in a number of locations. (B) An example of three split sediment cores.

FIGURE 3: Participants using iPads in the field (A) and in the classroom (B).

Global Positioning System (GPS)

GPS units were used by participants to collect points of interest during the field course and to provide spatial data that would be directly comparable to previously collected waypoints. This included the locations of sediment cores, photographs, videos, surface samples, and ground penetrating radar lines.

iPads

iPads (generation 2) enabled with 3G data communication technology were distributed to the 20 participants prior to the summer 2011 course. Participants were able to visualize, display, and share high-resolution digital elevation data, sediment core transects, and subsurface geophysical data collected for the field course (Fig. 3A). Further, participants extensively used the iPads for documenting their field experience by collecting visual data for their projects through the use of the built-in camera. Notes were also taken digitally in the field, and final presentations concerning their research findings were constructed. All of these field uses were accomplished via several apps (Table I).

Classroom Course Objectives

As a companion to this summer course, mostly the same cohort of participants enrolled in a classroom-based, semester-long oceanography class in fall 2011 (ESCI 511) designed to further bolster knowledge in marine geologic and oceanographic content, with a full traditional lecture and assignment-based classroom course. The reported demographics of 15 participants include 7% African American participants, 27% Hispanic participants, and 66% Caucasian participants with an average age range between 44 and 53 y (five participants did not complete the survey). The course content (see supplemental file for Classroom Exercises; available at: http://dx.doi.org/10.5408/12-318s1) included such topics as ocean basins, sedimentation, nearshore and offshore processes, coastal habitats, and coastal hazards. The course objectives were to (1) bolster oceanographic content knowledge, (2) clarify misconceptions, and (3) improve scientific communication skills through presentations and weekly reflections.

Classroom Uses of iPads

The fall academic semester course intended to fully integrate the use of iPads into a traditional classroom setting (Fig. 3B). Lecture slides, activities, materials, and weekly reflections/homeworks were all distributed digitally. In this paperless setting, each participant followed along with a digital copy of the lecture slides every class, taking notes as needed. Most homework and class activities were completed on participant's iPads, and these were confidentially submitted via the Dropbox app (Table I). Work was reviewed and graded by the instructor and returned in the Dropbox app.

PRE/POSTTEST

In July 2009, a modified version of the Geoscience Concept Inventory (Libarkin and Anderson, 2005) consisting of 28 questions was administered to a cohort of teachers. This test was again administered as a posttest in December 2009. This pre/posttest serves as a control for a typical group of teachers in the program. In July 2011 (i.e., just before iPads were introduced to the program), an expanded, modified version of the Geoscience Concept Inventory (Libarkin and Anderson, 2005) consisting of 33 questions was administered. This same test was then administered as a posttest in July 2012.

PRE/POSTTEST RESULTS

The July/December 2009 pre- and posttests yielded average scores of 70.1 and 88.9, respectively (prior to the addition of iPad technology). The difference between these tests was 18.8 points, serving as the control amount of change. The July 2011/2012 pre- and posttests yielded average results of 78.4 and 79.8, respectively. The difference between these tests was 1.4 points.

PARTICIPANT SURVEYS

As we were particularly interested in feedback associated with integrating iPads into our field and classroom settings, we developed surveys for our participants. Pre- and postsurvey questions were adapted from a similar study by

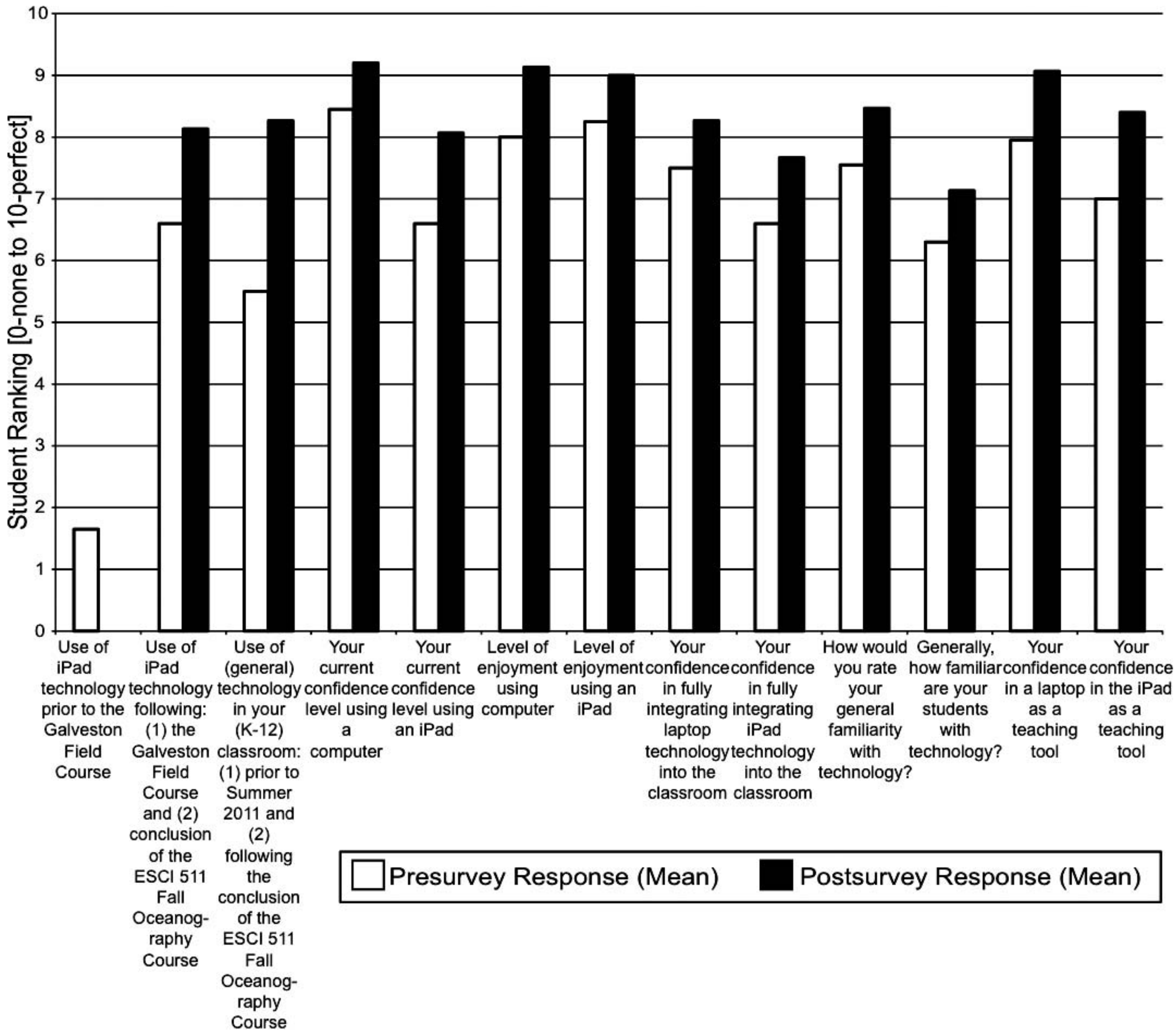

FIGURE 4: Pre- and postsurvey part one responses. Values are average results for all participants on a scale of 0–10 (0 = none, 1 = exceptionally low, 2 = particularly low, 3 = very low, 4 = low, 5 = neutral, 6 = high, 7 = very high, 8 = particularly high, 9 = exceptionally high, and 10 = perfect). Each question is shown below each set of responses.

Hoisch et al. (2010) examining the use of tablet personal computers (PCs) in a geoscience classroom. The confidential pre- and postsurveys given to participants were both nearly the same, with only minor changes between the two surveys, reflecting course-specific questions (i.e., specific differences between ESCI 511 and 515). These surveys were distributed to willing participants after the summer 2011 course (i.e., presurvey) and after the fall 2011 course (i.e., postsurvey). They were administered 5 mo apart, during which time the participants had returned to their regular teaching roles at K–12 schools. The surveys were split into three parts, each designed to capture a different measure of participant technology usage.

For part one, participants were asked to provide a ranking to questions on a scale of 0–10 (with the rankings as follows: 0 = none, 1 = exceptionally low, 2 = particularly low, 3 = very low, 4 = low, 5 = neutral, 6 = high, 7 = very high, 8 = particularly high, 9 = exceptionally high, and 10 = perfect). The responses from all participants were averaged for each question individually for both the pre- and postsurveys, thus allowing for a direct comparison (Figs. 4 and 5). Part two focused on how much time in number of hours the participants spent on certain tasks using technology. Part three posed short-answer questions intended to allow participants to fully and directly express their experience.

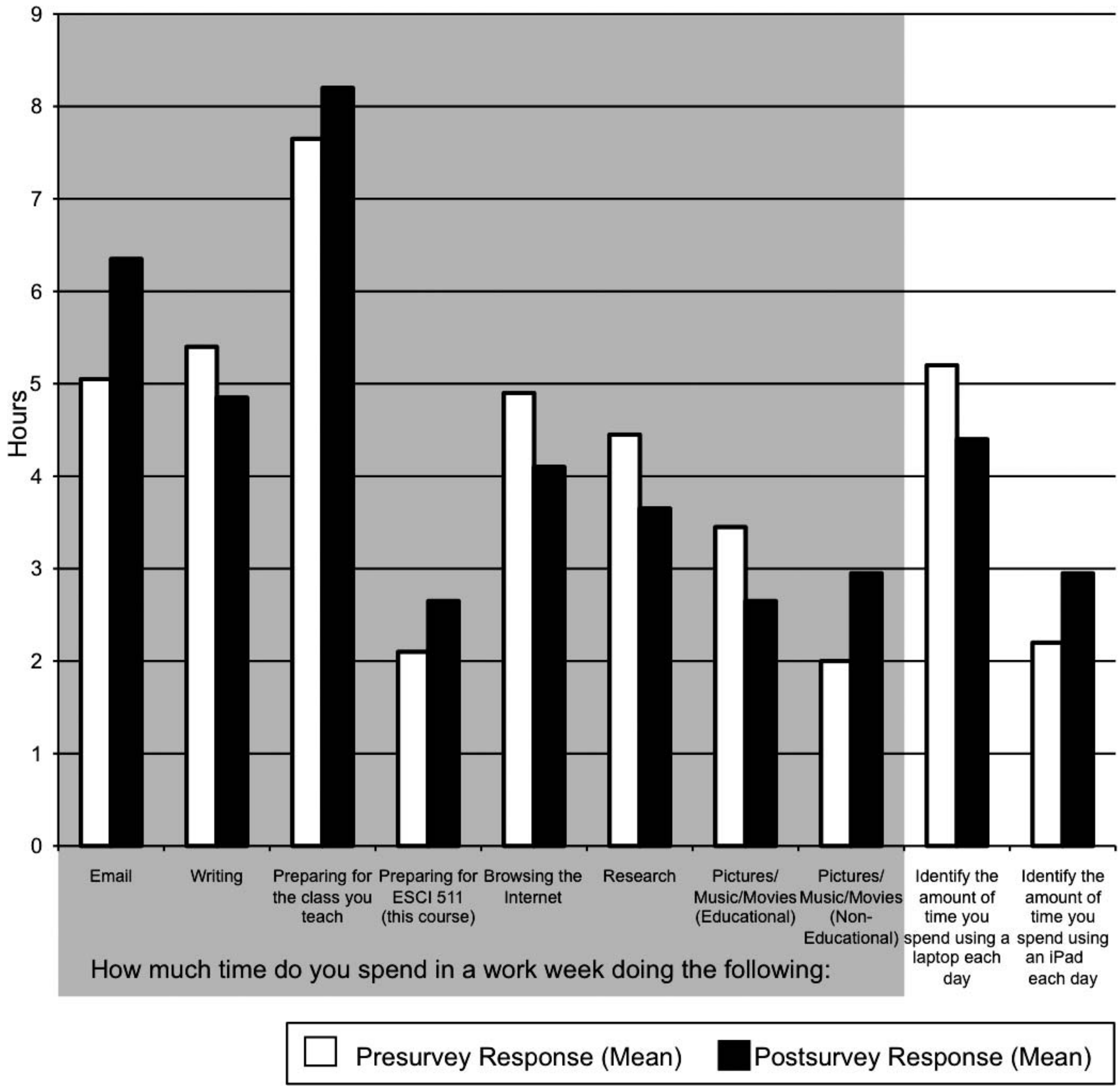

FIGURE 5: Pre- and postsurvey part two responses. Values are average results for all participants in either hours per week or hours per day, depending on the question. Inside the gray box, participant responses reflect how much time they spend in a work week doing certain activities. Outside of the gray box, participant responses reflect how much time they spend each day using a laptop versus an iPad. Each question is shown below each set of responses.

SURVEY RESULTS

Part one of the surveys had participants rank questions relating to their general confidence and enjoyment using technology. As a baseline, participants were asked about their use of iPad technology prior to the Galveston field course (i.e., the first course with iPads introduced). The average response for the participants "use of iPad technology prior to the Galveston field course" was between exceptionally and particularly low (an average ranking of 1.7). Use of iPad technology following the Galveston field course yielded an average response of 6.6 (between high and very high). The corresponding questions for which participants increased their ranking by a full-scale point, which we consider as having a significant impact on the participants, include:

(1) use of iPad technology following: (a) the Galveston field course and (b) conclusion of the ESCI 511 fall oceanography course (average 1.5 higher rank),
(2) use of (general) technology in your (K–12) classroom: (a) prior to summer 2011 and (b) following the conclusion of the ESCI 511 fall oceanography course (average 2.8 higher rank),
(3) current confidence level using an iPad (average 1.5 higher rank),
(4) level of enjoyment using computer (average 1.1 higher rank),
(5) confidence in fully integrating iPad technology into the classroom (average 1.1 higher rank),
(6) confidence in a laptop as a teaching tool (average 1.1 higher rank), and
(7) confidence in the iPad as a teaching tool (average 1.4 higher rank) (Fig. 4).

For all questions in part one of both surveys, which were meant to compare the response, the difference from the pre- and postsurveys showed average gains, ranging from a 0.8 to 2.8 increase (Fig. 4). The specifics on individual questions asked and the associated responses can be found in Fig. 4.

Part two of the participant surveys focused on the amount of time spent on specific tasks using technology. Comparison of the responses between the pre- and postsurveys shows that participants varied the amount of time they spent on certain tasks after the introduction to the iPad (Fig. 5). Based on their responses, participants spent less time each week on the following activities after the fall 2011 course: (1) writing (average 33 min less), (2) browsing the internet (average 48 min less), (3) research (average 48 min less), (4) pictures/music/movies (educational) (average 48 min less), in addition to (5) using a laptop each day (average 48 min less). Participants spent more time each week on the following activities after the fall 2011 course: (1) electronic mail (average 78 min more), (2) preparing for the class you teach (average 33 min more), (3) preparing for ESCI 511 (average 33 min more), (4) pictures/music/movies (noneducational) (average 57 min more), in addition to (5) using an iPad each day (average 45 min more) (Fig. 5).

Part three focused on short-answer questions. These questions captured an aspect that could not be quantitatively measured as in parts one and two. Also, it allowed participants to shed light on the impact these iPads had on their own students, as well as future potential. These responses can be used to gauge specific opinions of the participants, and representative answers are quoted in Table II.

DISCUSSION

Course Goals

In general, iPads were incorporated into both the field-based courses and the classroom successfully. Several specific uses for iPads were integrated towards reaching course goals:

Field Course Goals

Goal #1: Work in small groups designed to foster scientific independence and collaboration

In many cases, without prompting by instructors, participants were able to discuss their investigations in the field in detail, as they all had access to data, maps, and photographs via their iPads. Participants had access to the information that they collected during the day in the field that they could instantly share with others, and this led to meaningful field discussions that typically had not occurred in past courses. In past courses, there was always a time delay in disseminating data collected from the field to the participants. With iPads, discussions continued during the daily bus rides to and from the field site, and they could take notes based on their discussions while under way. Further, they could share data via 3G in the field and during their transit time. This amounted to more time spent working on projects beyond the allotted field time. In many cases, access to high-resolution historic maps and approximate current locations allowed participant's to develop and modify their investigations in real time while in the field. For example, if they identified an interesting feature, they could then look at satellite images, interpret the feature, and take a sediment core for documentation. This allowed the participants to maximize their time and thus increase field productivity.

Goal #2: Gain familiarity and mastery of scientific technology (ground penetrating radar, sediment coring, GPS handheld units)

Goal #3: Interpret scientific data in a historical context

Goal #4: Acquire field and laboratory experience

iPads were successfully integrated towards displaying, manipulating, and discussing the data generated by these devices. This was accomplished by sharing high-resolution PDFs in most cases. The assisted GPS available on the iPads was auxiliary to the handheld unit data, with the added benefit of high-resolution map overlays.

Goal #5: Ultimately share this experience with their own students

The iPad also offered a unique way for participants to document their entire experience. Participants were able to take photographs and videos seamlessly in the field, which included location information, and they were able to share files with one another. Further, their experiences could be displayed directly on the iPad, with no additional device necessary.

Classroom Course Goals

Goal #1: Bolster oceanographic content knowledge

Goal #2: Clarify misconceptions

Based on pre- and posttest data, there is no evidence to support that integrating iPads had any impact towards reaching these goals versus traditional teaching methods. The pre- and postdifference in 2011 (average 1.4 point increase) compared to a 2009 control cohort (average 18.8 point increase) is significantly less. We note that the cohort and content taught was slightly different between 2009 and 2011; therefore, caution should be exercised when comparing the point differentials, as this represents a typical spread between different cohorts over the years at Rice University in this type of assessment. Despite this, there does not appear to be any link to increased content knowledge due to incorporating iPads with pedagogical practices versus traditional practices.

iPads certainly were integrated well from a teaching perspective. During lectures, participants followed along with the slides on their iPads, taking notes as needed. They

TABLE II: Table describing representative pre- and postsurvey short-answer questions and responses.

Survey Questions	Participant Responses
Presurvey	
What are your expectations for the iPad in this course?	"I'm curious to see how we are going to use the iPad in this course… Before the [s]ummer course, I had no idea what an iPad was."
	"In this class as a student, I am hoping that the iPad will help the class be as close to paperless as possible."
Do you envision iPads as useful teaching tools?	"The iPad is so powerful [and] compact that it lends itself well for classroom/field work. And increasingly, it seems we are headed towards a paperless society."
	"I believe that the [iPad] could be a great teaching tool. As with any new tool, it requires training and practice by the educator."
	"…I would like to use it to show what can be done with different apps."
What do you think will be the most beneficial use of an iPad while taking this course (ESCI 511)?	"• notes and pictures of events • size [and] ease of carrying it; ease of use • access internet • record teachable moments • flexible use • friendly apps (easy to learn) • easy sharing/communicating…"
	"You don't have to lug around textbooks and paper. You can take it with you and complete any work anywhere."
What do you think will be the most beneficial use when introducing iPad technology in your own classroom/work day?	"The most beneficial use of the iPad in my classroom would be the numerous [apps] that are available. The apps will keep the students engaged and help the kinesthetic, visual and auditory learners."
	"…the ability to quickly record or share with others."
Postsurvey	
What were your expectations for the iPad during the ESCI 511 course? Were your expectations met? Please provide some specific examples of expectations and how they were met.	"I feel, after this course, much more comfortable using the iPad for planning, researching, taking notes, writing reports, and communicating. It is a great tool. One great thing is that I was able to save and develop ideas immediately after it came to my mind."
	"...we collected data, communicated, and submitted work [via] the iPad."
	"The iPad has surpassed my expectations in potential uses…"
Has your experience using iPads during the ESCI 511 fall oceanography course helped you envision them as useful teaching tools? Please provide some specific ways in which iPads could be used in a classroom. Include both obvious/common ways and more creative ideas.	"In our final project we used the iPad to establish a link between two different classrooms in different schools for a video-conference. The students were able to share ideas with another class. I used it a lot for researching when an idea occurred to me anytime-anywhere."
	"Their ease of portability is a feature students would relish just as I have. The portability would make them perfect for use in our outdoor learning activities involving writing observations, data collecting, digital imaging, etc."
Did your experience in the ESCI 511 fall oceanography course alleviate any perceived negative consequences in using an iPad in your classroom? If so how?	"In the beginning, I [experienced] much frustration in learning the basic operational tools in getting the iPad to do what my laptop does. With support [and] sharing from my classmates I quickly moved into a very comfortable level in using the iPad."
	"Yes. I thought of it more as a toy or novelty. Now I see that it has a lot of very purposeful and educational uses!"
Did your experience in the ESCI 511 fall oceanography course change your opinion on whether you think your students will be excited about using an iPad or what they will be excited about?	"… several kids told me they talked their parents into buying the apps that we used."

were able to zoom in and out, in order to see higher-resolution details of figures in lecture presentations. Some of their own side questions could be answered quickly by having access to the internet and all past activities and presentations.

Goal #3: Improve scientific communication skills through presentations and weekly reflections

Some participants used their iPads during their final presentations. Further, weekly reflections were generally completed and uploaded via iPads. Additionally, during weekly group assignments and activities, participants used their iPads as mobile visual aids for discussion purposes.

Participant Attitudes Regarding iPad Integration

Increased Aptitude for Technology

The most dramatic results gained from the pre- and postsurveys suggest an increase in the participant's aptitude for technology. In order to provide context for this study, we established a baseline for the students use of iPad technology prior to the Galveston field course (i.e., summer 2011 course). The average response was between exceptionally and particularly low (1.7), demonstrating that the participants had very little experience with iPads in general, much less in direct geoscience applications. After the summer 2011 field course, use of the iPad technology average ranking rose to between high and very high (6.6), and again increased after the fall 2011 course to an average of between particularly and exceptionally high (8.1). Additionally, the survey results from the participants suggest an increase in the general use of technology in their K–12 classrooms, confidence in integrating laptops into their classrooms, and level of confidence in using a computer. The use of the iPad positively affected the participants use of general (non-iPad) technology.

Participants as University Students

Our results suggest that if iPads are provided to participants, they certainly will use them. Also, the more comfortable participants become with the device, the more time they spend using it.

Our results indicate that when an iPad is introduced to Earth Science courses, participants tend to substitute about 45 min each day using it instead of a laptop. They spend more time each week on course-related preparation and electronic mail, and noneducational activities (i.e. pictures/music/movies). However, they also spend less time writing, browsing the internet, conducting research, and other educational activities (i.e., pictures/music/movies). Therefore, it is not clear that simply having iPads directly translates into higher participant productivity in traditional university courses, although this could partly be due to increased efficiency, leading to more free time.

Participants as Educators

Our surveys suggest that after iPads are introduced to educators, they will begin to incorporate the technology into their own classrooms. Also, the longer they do this, the more their confidence increases in fully integrating this technology into their own teaching practices. Accordingly, educators then spend more time preparing for the class they teach. Interestingly, our results also indicate that as confidence in an iPad as a teaching tool increases, confidence in using a laptop as a teaching tool also increases. There is also an increase in the level of familiarity of the participant's students with general technology after the introduction of iPads.

Practically speaking, there are two scenarios by which iPads can be incorporated into K–12 classrooms: one device for the teacher alone, or a classroom set for all students. While this is beyond the scope of this study, participants expressed an interest in approaching their districts towards having one classroom or school set. Participants even expressed an interest in writing a proposal to externally obtain these units. The participants did also note classroom uses for a single device. Examples include: as one of the "stations" in a science rotation for students to use a specific app (i.e., Google earth, National Aeronautics and Space Administration [NASA] apps; Table I), for easy, seamless videoconferencing between other classrooms (via the Skype app), as a document scanner in the classroom, as a camera/video camera to record student presentations, and for teacher productivity. Their portability was also noted as useful during classroom lectures. Therefore, single iPads could be useful, mainly due to their built-in cameras and the ability to perform many side tasks.

Field Course Assessment

The data collected from the field-based portion of the course were purely qualitative responses. This consisted of participant survey responses and an assessment by the field course instructors. A major use in this setting was file sharing and data access in the field through the use of 3G data technology. For example, participants were able to access, visualize, display, and share high-resolution digital elevation data, sediment core photographs, and subsurface geophysical data (Fig. 3A), as well as field note taking, all on one device. Additionally, participants were able to access their approximate locations in relation to modern and historic images using the built in GPS technology, thus establishing a framework for participants to further develop geospatial relationships in the field. The participants also documented their experiences through videos and photographs of themselves and others in the field, thereby collecting information that could be disseminated to their own students. All of these uses were accomplished via several apps (Table I).

Increased Productivity and Technology Substitution

On average, the participants reported spending ~7.4 h a day using both a laptop and an iPad (in both pre- and postsurveys). The amount of time remained roughly the same over the pre- and postsurveys; as previously mentioned, the teachers used the iPads for a total of 45 min. more per day and laptops 48 min. less per day after the course. Assuming that the amount of material that the teachers need to gather for their classes remains constant, it appears as though it takes the teachers less time to browse the internet, do research, and find pictures/movies/music with an iPad than without one (i.e., potentially becoming more efficient). This allows for the teachers' time to be spent on other activities, which includes an increased amount of time answering electronic mail. When given an iPad, the teachers prepared for the class that they taught 33 min more per work week than without an iPad. We interpret this increase as additional preparation to better their lessons. This was an unexpected result of incorporating the use of iPads with our cohort, and it highlights the potential of gaining increased work time in similar future efforts. An alternative interpretation could be that this extra time spent on class preparation resulted from the participant's learning curve associated with incorporating iPad technology; however, this remains unclear from our data.

Comparison with Other Technology Studies

Our results are similar to other studies that successfully integrated technology into Earth Science courses, and we share a few examples. Hesthammer et al. (2002) showed that a major benefit of incorporating digital photography (in their case a digital camera and PC) is that students can discuss photographs quickly. Guertin (2006) demonstrated that Palm Pilots allow students in the field to become more active learners in addition to integrating this technology in a unique application. Elkins (2009) discussed several specific uses for integrating iPod technology into field-based courses during transit time. Sherman-Morris et al. (2009) demonstrated the utility of using Google earth coupled with GPS units in a field-based class. Hoisch et al. (2010) documented that student's comfort level using tablet PCs increased through time. Further, our results are also consistent with these studies in terms of high levels of enjoyment using technology, and the ability for students to evaluate images close up. Combining a geographic information system (GIS) with field-based investigations of geology was considered to be part of a K–12 program's success in building geoscience skills (Almquist et al., 2011).

Pitfalls Associated with iPads

There were some issues associated with the integration of iPads. It took a significant time investment for the initial setup. An entire class day was committed to training the participants to use the iPads, set up electronic mail accounts, download applications (Table I), and use the internet. Throughout these courses, there was also a constant flow of questions related with iPad content, meaning class time occasionally was interrupted. Furthermore, this was often the cause of some frustration by the participants as they learned this new technology. The demographics demonstrate higher age ranges than traditional college courses (summer average age range between 43 and 52 y; fall average age range between 44 and 53 y), and it is possible some of these pitfalls can be associated with introducing foreign technology to a generation that has been used to traditional teaching methods. Furthermore, our data suggest that there is no link to increased content knowledge by integrating iPads versus traditional teaching methods. This is significant considering the time and money investments involved with integrating iPads.

CONCLUSIONS

We found several specific field and classroom uses for K–12 graduate outreach courses. From confidential pre- and postsurveys completed by K–12 educators participating in both field- and classroom-based Earth Science courses, we collected useful information that sheds light on integrating iPad technology. This cohort of participants allowed us to understand specific uses of this technology in a university field and classroom setting. Additionally, we were able to assess the iPad's impact towards reaching content-knowledge growth.

We found that when given iPads, participants spent more time preparing for these university outreach courses as students and for the classes they themselves teach. However, they also engaged in more noneducational activities, although it is possible this reflects more free time due to increased efficiency. The surveys also suggest that participants tended to substitute laptop for iPad time.

It is unclear if the iPads had a major impact on the traditional classroom outreach course (ESCI 511), although there certainly were many uses in the field-based course (ESCI 515). The latter is associated with the strengths of the iPad, namely, its mobility, and ability to seamlessly share and access data in the field. However, there is no evidence that integrating iPads increased content knowledge over traditional teaching methods.

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