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Exploring the Use of iPads to Investigate Forces and Motion in an Elementary Science Methods Course

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Abstract

Many science educators emphasize the need for meaningful science learning experiences and promote the idea of social constructivism in their methods classes, usually with inquiry-based activities that include physical manipulatives. However, the proliferation of technology in the nation's schools suggests the need to incorporate this trend into inquiry-based elementary classrooms. This paper describes a shared common course assignment on forces and motion in an elementary science methods course, in which the iPad was introduced to preservice teachers as a tool for developing understanding of key concepts and processes. The study focused on the aspects of iPad use that 98 elementary preservice teachers perceived as beneficial in the forces and motion unit. Participants discussed the utility of the iPad for recording and replaying test data, its potential for visualizing science phenomena, and its value for communicating science understanding. Additionally, participants described how the iPad influenced instructional efficiency, engagement, and social learning. The implications of these findings are described given the scientific and engineering practices outlined in the new *Framework for K-12 Science Education* (National Research Council, 2012).

There is a movement in education, in general, and in science education, in particular, toward virtual experiences. This trend is evident across all educational contexts, from higher education to the elementary grades (Sun, Lin, & Yu, 2008). Although direct science experiences are strongly emphasized in many elementary science methods classes, the increasing ubiquity of technology in US homes and schools suggests that virtual interactions will become the norm and that ignoring technology is counterproductive, even in the inquiry-based science classroom.

Moreover, educators need to model the use of technology as a tool for developing an understanding of science concepts and principles. Such an approach requires unique science pedagogical approaches, which are currently under examination by teacher educators, in-service teachers, and preservice teacher candidates.

As science teacher educators, we wrestled with the role of technology use in our elementary science methods course when our own College of Education purchased a limited number of iPads for use by faculty. The administration encouraged us to consider various ways in which this technology could be utilized in our teacher education program, especially in the preparation of teaching candidates. As a team, we decided to explore how iPads could be used to promote candidates' understanding of forces and motion and how the tool would be integrated into a common course assignment, the Design Project.

This effort was necessary because in our state teaching standards shape the knowledge, experiences, and interactions provided in each course. Candidates are expected to demonstrate 21st-century skills and knowledge, which includes information and communication literacy. In fact, information technology is a central knowledge strand in one of the state's initiatives (Partnership for 21st Century Skills, 2009). Additionally, our pedagogical approach as science educators is influenced by the new *Framework for K-12 Science Education* (National Research Council [NRC], 2012). We have particularly embraced the practices for K-12 science classrooms (p. 3):

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

By utilizing the iPads throughout our explorations with forces and motion, preservice teachers were exposed to the versatility of this technological tool. Many applications were tested, and in the process, our preservice teachers learned the importance of adjusting current practices to best serve their future learners in such dynamic virtual environments. This paper describes our experiences with the iPads, as well as those of the preservice teachers enrolled in our science methods classes. The following research question was addressed: What aspects of iPad use did preservice teachers perceive as beneficial in a unit on forces and motion?

Theoretical Framework

In the last half century, constructivist teaching practices have been widely promoted and employed in science education (Tobin, 1993). Of particular importance to science teachers is psychological constructivism, which stresses that learners actively construct knowledge through their interaction with phenomena, most often in the context of a group (Phillips, 2000). Constructivism stands in marked contrast to the transmission model of education, a teacher-dominated didactic approach that continues to dominate many classrooms. Constructivism itself is not monolithic. In particular, there is a branch of radical constructivist philosophy—perhaps best exemplified by Ernest von Glasserfeld's (1987) idealist ontology—which claims that all truth is constructed by human thought. Thus, our approach to constructivism is tempered by a belief in the importance of balancing students' direct experience of the world and constructed understandings about natural phenomena with an initiation into the scientific tradition (Matthews, 1994).

The work of a number of central constructivist theorists—Vygotsky, Bruner, Piaget, and Dewey—informs our understanding, as they highlight the importance of constructivism in the context of community. In particular, we view learning as an active process that occurs within a group and requires interactions among participants in that group (Salomon & Perkins, 1998). In addition, the concept of a community of practice (Wegner & Lave, 1991) is central to the conceptual framework of our college and promotes social learning among group members as they participate in shared activities. Such communities of practice have a joint sense of purpose, require a mutual engagement of their members, and develop a shared set of artifacts over time (Wegner, 1998).

Dialog is of central importance to the establishment and maintenance of an active and vibrant community of practice, and the rich discourse fostered by communities of practice is of paramount importance in the context of democratic education (Burbules, 1993). With the advent of the newest computer technologies, much work remains in understanding how these new tools will help individuals engage, explore, and explain the natural world and the role these tools will play as communities of practice mediate meaning in a social context.

Literature Review

Perhaps the greatest challenge of an individual's participation in a technological society is the pace at which change occurs. As advances are made, devices improved, and the speed of communications increased, the institutionalized pace of public education poses many challenges for its teachers and learners. In an information age, curricular demands have been expanded, requiring that more is learned in the same academic year. Accountability has added much stress to a group of professionals that must work within numerous constraints—time, support, and budget. And of course, as new technologies are added to classrooms across our nation, minimal-quality professional development is made available to the teaching force. Such changes influence the work of the teacher, as well as that of the teacher educator.

Technology use in a classroom means different things to different people. Researchers have explored how technology-based lessons (Sun et a., 2008), as well as technology-supported lessons (Edelson, 2001), influence student learning. Whether or not technology tools serve as the only learning tool or one of many learning tools, lessons with technology integration are expected of teachers in 21st-century classrooms. The literature review focuses on research that supports the ways in which we incorporated the iPads into the Design Project (DP), an inquiry-based project that explored forces and motion with technology as a support tool.

Uses of Technology as Learning Tools

The integration of digital technologies has been promoted in classrooms for many purposes—from tools for instructional delivery to student research and communication. For example, Internet use is a common mechanism for technology integration. Several research reports described students' engagement in Internet-based searches for information (Waight & Abd-El-Khalick, 2007; Williams, 2008). In other instances, students have used the Internet as a tool for communication with both peers and research scientists (Mistler-Jackson & Songer, 2000) or to access the most current scientific knowledge yet to be published in textbooks (Hill & Hannafin, 2001).

An additional use of technology proposed for elementary and middle grades classrooms is to enable students to self-monitor and self-evaluate their learning. Wegerif et al. (2003) observed that when students interacted with a computer and peers the computer delivered immediate feedback to group members. Similarly, web-based games have prompted yet another venue for assessing individuals' understanding (Baser & Yildirim, 2012; Wegerif et al., 2003). Not only can computer-based responses provide quick access to assessment data, but these types of assessments have the potential to inform teachers about student progress (Williams, 2008).

Literature also suggests how technology has been used in classrooms as a means to access, collect, and report data (Edelson, 2001). In some cases data collection is supported through the use of handheld devices (Norris & Solloway, 2003). Rodrigues (2007) described the experience of one elementary teacher who had students build race cars; they then used motion sensors to collect trial data during the investigation. Though this may not match the philosophical orientation of all science educators, the suggestion to have students use classroom technology to collect data (as a simplified process) and focus on the content being addressed rather than the mechanics of data collection is worthy of consideration (Webb, 2005).

From virtual-world dissections to constructing civilizations, computer simulations have been used to promote students' access to models and data that they would not be able to experience directly. In the Create-A-World curriculum, computers enable middle grades students' access to weather and climate data from around the world (Edelson, 2001). Similarly, Mistler-Jackson and Songer (2000) pointed to the possibilities afforded by access to real-time satellite imagery. In a sixth-grade classroom, students used the computer to investigate simulations of an ecological system (Waight & Abd-El-Khalick, 2007). As stated by Webb (2005, p. 728), "Computer simulations provide new affordances for learning, particularly where they are based on phenomena that cannot be easily observed and explored in the real world."

Classroom technology shows promise as a vehicle for allowing students to share the science understandings they have developed through classroom activity. Edelson (2001) pointed out that computers are unique presentation tools that allow students to combine text, audio, and graphics to share knowledge in multiple formats. Additionally, both Cox and Webb (2004) and Rodrigues (2007) referred to the potential of such technologies in enabling students to make multimedia presentations. Luehmann and Frink (2012) found that it provided middle grades students experiences "that capitalize on social networks to support interpretation and meaning-making" and "that engage learners centrally in the authentic and core practices of a given discourse" (p. 824). These researchers have argued that using Web 2.0 technologies in science classrooms supports the "intersection of the goals of reform-based science goals and the meaning-making practices enabled by newer technologies" and allows for easy viewing and creation of content that allows others to interact with the content created" (Luehmann & Frink, 2012, p. 835).

Concerns/Barriers

The success of technology use in elementary classrooms has been well documented, yet some educators have expressed concern about its use in that context. One issue repeatedly reported as problematic is that teachers do not have the training or support to implement classroom technologies in meaningful ways. In one study conducted in Turkey, teachers reported that they did not know how to implement activities using classroom technology (Baser & Yildirim, 2012). Williams (2008) described the struggles of a fifth-grade teacher in the United States who had acquired new computer equipment for his classroom but was uncertain as to how to incorporate it into instruction. An additional concern related specifically to teacher implementation of technology is how it is utilized—rather than being a resource that promotes more reform-based instruction, teachers with limited training or understanding use it to supplement existing transmission models of teaching (Rodrigues, 2007).

Some teachers who have implemented technology-supported lessons in their classrooms have described the technology as a distraction for students or have noted that students do not use the tools as intended (Baser & Yildirim, 2012). In using the Internet to research a particular science topic, for example, students tended to search for the right answer rather than engage in the task in an inquiry-based manner (Wallace, Kupperman, Krajcik, & Soloway, 2000). In another example, students came to associate technology with group work. Rather than use the technology as a tool for collaboration, they planned how to divide the work to get it done most quickly (Waight & Abd-El-Khalick, 2007).

One final concern related to technology use in elementary classes is that in some instances the use of technology may undermine or replace students' direct experiences with science processes. In one study, students engaged in a virtual, computer-based modeling experience to help them become familiar with common lab equipment such as microscopes and thermometers. This was in place of the children interacting with the actual measurement tools (Sun et al., 2008). Such technology-based lessons for elementary students do a disservice when supplies are available because younger students' general developmental level requires more concrete experience (Driver, 1989).

iPads as a Technology Learning Tool

While much potential exists for technology use in the classroom, the introduction of Apple's iPad provides a new multitool—a device that can be used for a variety of purposes. Apple's iPad is similar to other Apple technology devices like the iPod Touch and iPhone in that users can download for free (or at cost), applications (more commonly referred to as *apps*) to use on their devices. These apps are software programs that provide the user access to entertainment games, facts and figures, simulations, communication, and data sharing. Apps can also enhance the daily and frequent uses of such applications as the timer, calculator, camera, flashlight, and alarm clock.

Because iPads are so new, little published research has been conducted on their use in educational settings. The few existing publications provide a description of how iPads have been used in classrooms thus far. Meurant's (2010) work provided an introduction to the iPad and its capabilities shortly after the initial release of the device. Saine (2012) described the practices of several different classroom teachers who used iPads to support instruction. Approaches included using apps on the iPad to create and animate stories, as well as using the camera function to photograph and publish pictures related to different geometry terms.

Although the use of iPads shows promise in educational settings, some educators have expressed concerns. In a study focused on apps specifically targeted for education, Murray and Olcese (2011) reported that current apps do not match modern theories of learning, emphasizing outdated transmission models. They stated, however, that the iPad provides some promise for teachers and students to engage in learning activities that would have been impossible in the past.

Clearly, the lack of literature available on a tool with such accelerated popularity inhibits educators seeking ideas for use in a formal learning context. This study adds to the small but growing body of literature on iPad use by sharing the perceptions of our preservice elementary teachers as they learned new science content and applications of the iPad through activities appropriate for use in their future elementary classrooms.

Methods

Context

The authors of this study are instructors of an elementary science methods course within an undergraduate elementary education program. In the fall semester of 2012, we taught 135 elementary teaching candidates in six traditional cohorts (five on-campus; one off-campus) and one part-time, nontraditional cohort (off-campus). Those candidates from the traditional cohorts are first-semester seniors who had been enrolled in a 16-hour block of courses that included methods courses in elementary mathematics, social studies, intermediate language arts, and science. Candidates attended classes twice a week for 10 weeks and then spent the last 5 weeks in a full-time practicum setting. The part-time cohort met one night a week for 16 weeks. Regardless of the arrangement, our elementary science methods courses include common assignments, one of which requires the use of iPads and is the focus of this paper: the Design Project (DP).

As a culminating experience in our force and motion unit, the candidates formed small groups (typically two to three people) and designed a moving vehicle. They built their first prototype, collected time and distance data during their first round of experimental trials, and modified their prototype based on the data. Then, with their second prototype they collected time and distance data during their second round of experimental trials.

Throughout this process, the instructors required the groups to use an iPad to take photos and videos using the camera app of their construction process of the two prototypes, as well as at least one video of an experimental trial. In addition, and to varying degrees, we asked students to use several other content and presentation related apps on the iPad within our force and motion unit or as part of their write-up of their DP. These apps included, but are not limited to Exploriments Weight & Mass, Educreations, Dropbox, RCB Travel, Gravity HD, Acceleration, Drainworks LT, and iMovie. While the students had access to a variety of technologies throughout the project (digital still cameras, personal laptops, a full computer lab, and an interactive white board) the iPads were the primary technology used in the context of this unit, both by students' personal choice and in response to the specific requirements of the project. (***Editor's Note:*** Website URLs are listed in the Resources section at the end of this paper)

Data Collection and Analysis

A survey focused on the preservice teachers' experiences using iPads in our elementary science methods courses was administered electronically (SurveyNet) by the college research assistant and was distributed to all 135 students enrolled in the science methods course at the end of the 16-week fall semester 2012. Our survey, which was piloted the previous academic year, included nine items (eight open-ended, one Likert scale item) about candidates' iPad experiences during the DP. Of the nine survey items, seven were related to the research question about the aspects of iPad use that preservice teachers perceived as beneficial. These seven survey items are included in the appendix. Survey questions asked candidates to describe their use of and experiences with the iPad and to evaluate the various apps utilized for the project as well as during the forces and motion unit.

Once grades had been posted, the administrator released the survey data to the research team for analysis. The response rate was 72.6% (98 out of 135). On average, each open-ended question generated 90-92 qualitative responses for review and analysis. The rating of apps (Likert scale) yielded quantitative data that will be used primarily for instructional purposes; consequently, we noted trends in recommended apps and those frequently referenced by candidates in open-ended responses.

We individually coded a subset of the open-ended response data using constant-comparative methods (Charmaz, 2006). Keywords and common phrases were identified in the data subset and shared with all authors. Potential codes were compared, allowing us to establish and define four broad categories for organizing data (record/replay data, visualize, presentation, tool).

A coding template was created, thus allowing the research team to code independently all survey data using these four categories. As responses were analyzed, candidates' iPad experiences were interpreted as positive, negative, or neutral within the four broader categories. Responses were categorized according to affective key words or phrases. For example, descriptors with positive intonations were identified by candidates' use of such terms as *liked*, *enjoyed*, *helped*, and *awesome*. Negative responses were more likely to imply dissatisfaction, confusion, or a waste of time. Through the process of categorical aggregation (Stake, 1995), these collections of responses contributed to preliminary themes. Table 1 summarizes and illustrates our coding protocol during our analysis process.

Table 1
Protocol for Data Analysis

Preliminary Categories for Analysis (Defined as)	Positive Experience	Neutral Experience	Negative Experience
Record/Replay Data (responses related to data collection)	"The iPads were helpful in recording data."	"After the project, we were able to replay and make note of the science concepts."	"I think that the iPads were not needed and that a camera would have done the job just as well."
Visualize (responses related to seeing something that is abstract or simulated)	"The gravity app was pretty awesome. It really helped me to understand the differences in gravity, mass and weight."	"We explored one app about weight and gravity."	" . . .was confused by the app though. I didn't entirely understand the point of all of the things on it."
Presentation (responses related to sharing analysis of data, findings, and science understandings)	"It allowed us to quickly make a website that explained all the physics behind the experiment, videos and pictures included."	"We were able to look back at pictures and videos while we also looked up information that we needed on the Internet."	"We also built a website through the iPad which I struggled with and it would have been a lot easier to use a laptop."

Tool (responses related to the iPad itself when used as a tool to accomplish specific educational tasks)	"Having the iPad during the experiment was a source in itself, because if we did not understand a particular equation to use when finding our data, we could have easily looked it up on the Internet."	"To be honest, the iPad had nothing to do with my understanding."	"It took me more time to figure out what to do and what was happening on the actual iPad than I was able to focus on the science content."

Data analyses were performed independently by three of the four authors and shared electronically. A fourth author collected these analyses and reviewed coding choices to confirm basic intercoder agreement. Finally, the team met to explore the emerging patterns in candidates' responses. These emerging patterns within the categories listed in Table 1 are discussed in the findings section.

Findings

Based on the qualitative responses of the preservice elementary teachers, we identified four major themes related to use of the iPad as an instructional tool in an inquiry-based science setting. The first three themes related to actions that the participants engaged in with the iPads, recording and replaying data, visualizing science concepts, and presenting their understandings of science content. The fourth major theme to emerge centered on the iPad as a classroom tool. Preservice elementary teachers reported its potential for improving efficiency, 21st-century education outcomes, engagement, and social learning.

Record/Replay Data

One of the emergent themes from the data centered on candidates' remarks about the benefit of iPad use for taking photos, recording test runs and replaying videos during the data collection, analysis, and reporting stages of the DP. Our preservice teachers expressed an appreciation for a device that could be used in various ways as a data collection tool. Though a requirement of the DP was for preservice teachers to include one video of an experimental trial, we observed many groups recording videos of multiple trials.

Preservice teachers mentioned the advantages of replaying their videos during different aspects of the DP process. By recording and replaying video trial data, in particular, many indicated that their ability to observe and analyze science phenomena was enhanced. They mentioned that video evidence collected during their construction phase allowed group members to "see issues that needed to be improved" to vehicle prototypes. In addition, respondents commented on how rewatching the videos (sometimes in slow motion), helped them analyze the movement of these vehicles and better understand the concepts of forces, including friction and gravity. For example, one respondent explained, "While watching the replays, I was able to see the science content present in our project (friction, speed)."

We also noted that a number of candidates mentioned how replay reinforced their understanding of the underlying science, as represented by the following comments:

> "We could re-watch the experiment and comment on the physics that was occurring"

> "I was able to use the iPad to video my car in motion, and then slow it down and replay it to see the laws of motion more clearly."

In addition, the use of the iPads as a data collection device was often considered as beneficial in the initiation of small group discussions of science concepts, as it provided a focal device to display data. The DP required preservice teachers to work in small groups where one person might be holding a timer, another person recording videos or images using the iPad, and another person handling the vehicle. Replaying videos was seen as a beneficial use of the iPad, because preservice teachers did not have to spend as much time straining to watch their vehicles in the moment while also participating in the facilitation of the trial: "We were able to see what was happening instead of relying on what we thought we saw."

Candidates mentioned how replaying video trials improved their observations of their vehicles by giving them multiple chances to observe the same trial, giving them "another chance to see something you might have missed in the first attempt by replaying the attempt." Preservice teachers also mentioned how viewing videos of experimental trials helped group members reach consensus about what they observed: "By using the iPad, if one partner seen [sic] something the others did not, we were able to replay and every member in the group could see what they saw."

Few negative or critical neutral responses were submitted related to using the iPad as a data collection tool for recording and replaying. Interestingly, these responses did not discuss the videos as being useless or of no benefit to the preservice teachers, but mentioned that the iPad itself was not necessary to collect this type of data, for example,

> "I think that the iPads were not needed and that a camera would have done the job just as well."
>
> "This was just as easily done on our cell phones."

Though few responses explicitly mentioned cell phones, many of the preservice teacher groups had a member with a cell phone camera capable of taking photos and videos and were observed using them in the DP. Interestingly, these were often iPhones, which could be considered for our purposes like mini-iPads, as they would be using the same camera app in either the iPad or iPhone.

Visualize

A vast majority of the survey respondents reflected explicitly on the usefulness of the iPads as a tool for visualizing situations that are difficult or impossible to experience directly. Many conflated the process of exploring within a simulation with the concept of scientific exploration in general. They noted, for example, that "it is important to be able to have exploration in the classroom, even when students can not physically be in a certain environment."

The simulation experience provided by the Weight and Mass app—an app that allowed preservice teachers to compare weights and masses of objects on earth and the moon using virtual tools including a spring scale and a balance—seemed particularly useful for students. Indeed, of all the iPad-specific apps, this particular program was most commonly cited by respondents as valuable, likely due to the fact that it helped students interact with an idea that is impossible to experience directly. As one candidate wrote, "We could not go to the moon to weigh ourselves; therefore, the next best thing is for us to have an activity that allows us to make connections."

In addition to the benefits of displaying simulations of experiences students could not have in real life, the iPad was seen as useful for extending senses, especially in playing back video of experiments for analysis. Preservice teachers found the iPad camera valuable in the process of measurement by replaying the video to see how high a water bottle rocket flew or how long it took for a gravity-powered car to go a certain distance. Repeatedly, preservice teachers noted the value of the *visual* image as a part of the process of abstracting science knowledge, as discussed in the record/replay section. Once they had captured images, students also found iPads useful for interacting with these visuals. Thus, even as their ideas became more abstract, they were still able to apply and refine them with respect to images they captured as they did their own concrete explorations.

Preservice teachers made few negative comments about the iPad as a tool for visualization. Some of the negative comments were technical rather than conceptual, with complaints that a given app was “counter-intuitive” or the respondent was “confused.” However, in no case did these difficulties seem to outweigh the preservice teachers’ perceptions of the benefits of using the iPad for simulating situations that could not be experienced directly, nor did anyone comment negatively on the use of the iPad for creating visuals as a part of data collection and analysis.

Present

Preservice teachers were positive about the potential of the iPad as a presentation tool. As a part of the DP, small groups of preservice teachers were required to share the construction details of their creation, graphs displaying data, an explanation of the science content underlying their project, and a justification for why their creation should be chosen for use in a theme park. Many of the candidates indicated that the Educreations app played a role in the process. Educreations is an app that allows a user to upload from one to several digital images to the Educreations site. The user can then add both spoken voice and drawings to the images to explain what is happening in them. The preservice teachers appreciated several aspects about the app, including the ability to use multimedia to share what they had learned and the scientific understanding gained by reflecting on what had been learned.

The preservice teachers valued the opportunity for creativity and multimedia presentation allowed by the Educreations app. One preservice teacher explained, “The iPads and app were very helpful in this project because we could give a detailed explanation of the science concepts while drawing arrows and diagrams to visually show the concepts we were talking about.” Similarly, another preservice teacher welcomed the multimedia aspects of Educreations, reporting that the app “not only allowed you to express your ideas through a picture, but it also allowed you to manipulate that picture to give motion to the picture and help you better explain and understand a concept, whether you a relaying this information to another students [sic] or to yourself in the future.”

Several preservice teachers suggested that the process of creating the science content explanation forced them to consider and refine their own understanding. For example, one preservice teacher stated, “We had to explain what we learned through apps on the iPad, and explaining a concept to someone else always helps you learn.” Another commented that using “the iPad app where you could use a photograph to explain and visually demonstrate underlying science concepts really allowed me to gain a lot of understanding. (Educreations).”

As they reflected on their roles as future teachers, seven of the preservice teachers were positive enough that they said they planned to use Educreations in their future classrooms. They cited its usefulness for science teaching as well as other disciplines as a contributing factor.

While the preponderance of comments related to Educreations were positive, a few students were either neutral or negative in their assessment of the app. Preservice teachers who fell into this group tended to say that, although they enjoyed using Educreations, they did not believe it actually contributed to their understanding of the science content.

While Educreations was overwhelmingly the most frequently cited example of using the iPad to share what had been learned, a small number also mentioned graphing as an important tool for communicating results. Preservice teachers were introduced to the website Create-a-Graph. This kid-friendly website allows users to choose a type of graph along with the parameters. Users then enter the data, and the website creates a graph that can be exported in html or pdf versions for use in a variety of ways. While this website can be accessed using any web-enabled device, the preservice teachers tended to access it through the iPads. An example of preservice teacher sentiment related to the graphing program is reflected in the following: “Creating the graphs was an engaging, time efficient, and easily accessible way of representing this data.”

Use as a Classroom Tool

In addition to the comments about specific uses of iPads described in the preceding sections, a number of the survey responses discussed the iPads as classroom learning tools, in general, reflecting on their ease of use and value both within and beyond the science classroom. These ideas were organized around the themes of efficiency, 21st-century education, engagement, and social learning.

Efficiency. The iPad is essentially a tablet computer, and preservice teachers identified many of the same benefits and drawbacks typically expected from interactions with other computer technologies. In particular, they reflected both on the way the iPads made many tasks more efficient, as well as their own frustrations with technical issues. In particular, preservice teachers found value in having access to the Internet, a camera, presentation tools, and content-specific apps all on a single light, compact device. One respondent wrote, “Using the iPad made it easier to keep all the photos, charts, and information all in one place. It was nice to take it outside to take a photo and enter the information at the same time.”

However, numerous problems were associated with figuring out how to do things on the device, logging into various apps, and transferring files. Several students complained that these difficulties inhibited their learning: “It took me more time to figure out what to do and what was happening on the actual iPad than I was able to focus on the science content.”

Additionally, some preservice teachers found that the iPad was cumbersome for certain tasks, such as building their website, and preferred the laptop for these tasks. While references to technical problems were relatively common, we suspect that they were more prevalent among people who self-identified as nontraditional, older students, due to statements such as the following: “I was frustrated in trying to use it because all the 'younger' students knew how to manipulate it, but it took my [sic] longer because I was not familiar.”

21st-Century Education. A number of the preservice teachers in our study expressed an assumption that, like them or not, tools like the iPad will be a part of the 21st-century classroom and that teachers would have to become accustomed to using them in that context. Broadly, these comments expressed two interrelated ideas, noting that elementary students would need opportunities to develop technical skills in schools, since jobs of the future would require these skills, and that classrooms of the future would be filled with technology that teachers would be expected to use. Thus, they combined ideas about students' future career needs (e.g., "Any access they can get to becoming more familiar with these kinds of devices will not only help them in school, but also in their careers") with their sense of what they themselves would face when out in the schools ("I feel that the use of the iPad broadened our horizons, especially considering that technology is quickly becoming a huge part of the classroom of the future.").

Engagement. Many of the respondents described the tools as "engaging," "fun," "exciting," or "like a game…amusing." This attitude held true for their reflection on their own experience as well as their discussion of why they thought the iPads would be good to use with their students. Many of these comments expressed a general sentiment that technology—especially the newest gadget like an iPad—is inherently fun, but some homed in on the touchscreen feature as being particularly important. Preservice teachers were split about whether the iPads were useful for developing scientific understanding, with some noting, for example, "The iPad had nothing to do with my understanding," or "The iPads didn't help me understand science content." Others wrote, "I feel this really improved my understanding," and "It provides a creative sense of learning."

Social Learning. For this project, the iPad was used in the context of a small-group activity, and preservice teachers shared an iPad in groups of two or more. Preservice teachers were positive about the way the tool itself helped them collaborate. For example, one respondent wrote, "I was able to share information, reflect on class days, and really work with classmates to come up with prototypes. I think they are great for collaborative learning and reflections." Many preservice teachers perceived this required collaboration itself as valuable, writing, for example,

> "We worked together using one iPad. It was beneficial because we had to collaborate on a lot of stuff because we only had one."
>
> "I was able to generate questions on my own but also with partners that think differently than I do so I was given a new perspective."

In addition to the practical benefits of a tool allowing people to share files and information, the visual nature of the tool helped preservice teachers talk about science with one another. As one respondent wrote, "We were able to work together to share our insight on the photos, and it was easier for the other person to explain their ideas with the visuals."

Yet, requiring preservice teachers to work on the iPads with partners was perceived as both beneficial and problematic in terms of the moment-to-moment operation of the device. For example, one respondent wrote,

> Sometimes I enjoyed using the iPad with a partner, while other times it confused me. I am not the best at technology so it was good for me to have a partner who could show me how to use the features…[but sometimes] my partner would click a button I did not know existed, and we would end up with a screen and I would not know how we got there.

Overall, a tension arose between the benefits of collaboration and the inevitable inequity that arises when people share a tool: "It was helpful as we were able to gather around and work together when working with data." Others expressed a difficulty working with a partner who took control of the iPad.

Discussion

When confronted with a new tool, no matter how shiny and exciting, one must always ask whether its use helps solve real problems. The preservice teachers' perceptions of iPad use in the DP supported various practices from the new *Framework for K-12 Science Education* (NRC, 2012). Therefore, the iPad has potential as a Web 2.0 technology that supports the "intersection of the goals of reform-based science goals and the meaning-making practices enabled by newer technologies" (Luehmann & Frink, 2012, p. 835) when used in support of concrete-based experiences within communities of practice. Table 2 shows a summary of which themes from the data support each of the practices from the *Framework* (NRC, 2012).

Table 2
Perceived Benefits of Using iPads as Compared With Practices From the *Framework* (NRC, 2012)

Practices From *Framework* (NRC, 2012)	Perceived Benefits of iPad Use			
	Record/ Replay	Visualize	Present	Classroom Tool
1. Asking questions/ defining problems	X			X
2. Developing and using models	X	X		
3. Planning/carrying out investigations	X			X
4. Analyzing and interpreting data	X			
5. Using mathematics and computational thinking	X	X	X	X
6. Constructing explanations/designing solutions	X		X	
7. Engaging in argument from evidence	X		X	
8. Obtaining, evaluating, communicating information			X	X

Asking Questions (for Science) and Defining Problems (for Engineering)

The DP was an inherently engaging task for our preservice teachers, driven by the engineering problems they faced and the playful nature of the task at large. This would have been true whether or not we used computer technologies as a part of this task. Indeed, iPads were largely extraneous to the preservice teachers' original enthusiasm for the DP and their initial thinking about the design problems they would face. However, as they worked, they quickly engaged the technology as an integral part of the design process, using the camera to document their brainstorming and photograph the construction of their vehicles. Before long, the excitement for the project as a whole and the pleasure they gained from the use of the iPads—well documented in the results of the survey—were bound together. This pervasive positive emotion set the stage for focused attention on the design challenges they faced.

Moreover, this attention translated into a stronger sense of ownership in the process from the beginning, as the technology facilitated students' personal connection to the task and related questions. Luehmann and Frink (2012) found a similar benefit from the use of

Web 2.0 technologies such as blogging with two middle grades teachers, finding that it "encouraged voices not often heard in classrooms" and "nurtured a sense of ownership of learning" (p. 833). However, the presence of a tool by itself is not sufficient to guarantee students' engagement in defining problems and asking questions. Rather, used thoughtfully and intentionally, technologies can set the emotional stage for student connection and can be fully woven into the questioning process.

Developing and Using Models

At many stages of the DP, the preservice teachers used iPads to abstract ideas from physical experience: videotaping and discussing footage, photographing and drawing on photographs, graphing and exploring relationships represented by the graphs, and modeling content using apps. Preservice teachers' survey responses showed that these experiences were perceived as valuable, both in terms of an understanding of the underlying content and completion of the project as a whole. The benefits of the iPads in the modeling process allowed students to extend their senses into realms into which they would otherwise not have access.

For example, through the use of the Weight and Mass app, the preservice teachers were able to explore and model the concepts related to gravity in a simulated environment to which they would never be able to travel. In addition, the camera provided an important data source for the preservice teachers as they began to develop conceptual models. As Edelson (2001) noted,

> Inter-active media can often improve upon the real world for presenting discrepant events. For example, a phenomenon that is inaccessible to direct observation can be presented in a recorded or simulated form. Thus, phenomena that are too small or too large, too fast or too slow, too hot or too cold for direct observation can all be reproduced using recording or simulation technologies. (p. 376)

Planning and Carrying Out Investigations

As preservice teachers carried out their investigations of their vehicles in motion, they took photos of their construction process as well as their experimental set-ups. They also took videos of their experimental trials of each of their prototypes. Their overwhelmingly positive responses concerning the ability of the iPad to record and replay their images and videos showed the benefit to preservice teachers in having their data in one place to refer to as they went through their investigation process.

As opposed to the use of technology to provide data for investigations as in Edelson (2001), in this situation the iPad served as one tool with which preservice teachers could collect, store, and display data throughout their experimental process. They consistently commented on the benefit of the iPad for this purpose during the DP. Therefore, even though few responses were critical related to the iPad's use as a data collection tool for images and videos (preferring substitutes such as a digital camera or a phone), the act of taking the videos of experimental trials and replaying them was overwhelmingly perceived as positive and deemed beneficial by the preservice teachers. This finding supports research that shows the benefits of using technology tools in investigations to support students in self-management of their progress through experimental trials, freeing the teacher to help students develop questions and facilitate meaning-making (Webb, 2005).

Analyzing and Interpreting Data

The responses from preservice teachers focused on the iPad as a tool not only for collecting data, but for supporting their groups. They analyzed the movement of their vehicles and interpreted how force and motion concepts were related to the movement of their vehicles using their images and videos as evidence, in addition to their time and distance records. Streamlining data collection with tools has been shown to aid teachers and students in focusing on evaluating the performance of constructions rather than the construction process itself (Rodrigues, 2007).

In addition, using technology tools has also been shown to aid students in focusing on the development of concepts rather than mechanical procedures of investigations (Webb, 2005). Though the preservice teachers were mixed in their responses concerning how the iPad contributed to their understanding of science content, they frequently described how recording and replaying images and videos in the DP helped their groups to connect science concepts of forces and motion to their specific vehicle performance—though this discussion was not explicit in terms of the concepts involved.

Using Mathematics and Computational Thinking

Though the preservice teachers did not mention the use of their recorded videos as a resource for recording time and distance information, we saw groups replaying videos of experimental trials to measure the motion of their vehicles. Videos of trials were used by preservice teachers to check for consistent measurements to aid in more accurate mathematical relationships for evaluating the performance of their vehicles. Again, in situations where peoples' senses prevent them from being able to observe closely phenomenon, such as vehicles in motion, being able to replay videos at speeds slower than reality can aid in seeing events that happen too quickly for the human mind to process.

The iPads also functioned as efficient graphing tools when the students utilized an online graphing program to represent and analyze their data. As many respondents noted, the convenience of having a single tool function in a variety of ways (e.g., stop-watch, video camera, calculator, Internet resource, graphing program) was of particular value in a complex, multidimensional project like the DP. This ability to have one device that provides a central location for multiple data collection and analysis tools is one of the great potentials offered by the iPad.

In addition to the direct work on their DP, students also found value in the use of the Weight and Mass app to develop background understanding of the mathematical and conceptual relationships between weight and mass. This finding is unlike the work of Murray and Olcese (2011), who expressed concern over the large number of apps that emphasized a transmission model of information sharing. Instead, far from being only a calculator or computing device, the iPad helped students connect numerical relationships to the real world—albeit, in the case of weight and mass on the moon, a virtual version of the world.

The experiences of our participants suggest positive outcomes when the potential hoped for in Murray and Olcese's (2011) work is realized. Here again, the iPad is particularly suited for interactivity and allows students to gain a sense of connection and mastery through the use of a technological tool that enables them to exchange information in a variety of formats (Luehmann & Frink, 2012). Significantly, the benefits of the touchscreen were commonly noted by the preservice teachers and seemed to be an integral part of their internalizing the relationships they were exploring. Since many preservice teachers mistakenly referred to this connection as "hands-on," this experience likely had some of the value of direct exploration in that it was mediated by a pseudotactile interface.

Constructing Explanations (for Science) and Designing Solutions (for Engineering)

Preservice teachers commented on the benefit of recorded videos of experimental trials in initiating discussions of how the science related to the performance of their vehicles. The use of the camera/photo app on the iPad, therefore, is consistent with the use of a Web 2.0 technology as discussed by Luehmann and Frink (2012). This use of the iPad supported the practice of "socially constructing and categorizing content" using video/photo sharing (p. 825). Of particular value from an engineering standpoint were the videos students made as they were doing the initial building and testing of their vehicles, as this footage served to help them analyze design issues and make adjustments. As students worked through the design process, they also used the videos to help them develop initial explanations for the underlying science. In this way, the video data was intimately involved in their development of a conceptual lens through which they analyzed each iteration of their vehicle, as well as the final experimental trials.

Engaging in Argument From Evidence

In their presentations of their understandings of the science related to their constructions in the DP, students used images of their vehicles in the Educreations app. They appreciated being able to use not only their data tables and graphs, but also their images as visual evidence to support their ideas. The development of their science explanations within groups using the images, videos, and graphs was mostly seen as a positive experience. Many preservice teachers felt that the shared viewing of videos and construction of their Educreations explanations was due to the shared nature of the iPads within the DP. Communities of practice in science learning require cooperation between learners in constructing arguments through interactions with more or less knowledgeable peers, which is seen as a benefit of technology integration (Kim, Hannafin, & Bryan, 2007).

Obtaining, Evaluating, and Communicating Information

The preservice teachers were not dissimilar from students in other studies in viewing the Internet as a resource for information (Waight & Abd-El-Khalick, 2007). The use of technology for obtaining and evaluating information from the Internet has been argued as a benefit because it can promote student interaction with scientists rather than limit learning to potentially outdated ideas in a textbook (Kim et al., 2007; Mistler-Jackson & Songer, 2000), though these interactions require scaffolding in order to promote deeper content understanding (Kim et al., 2007). However, while a number of our respondents commented on the convenience of using the iPad to connect to the Internet, this capacity did not seem to be a central value in the context of the DP. The tool was used much more frequently for documenting and communicating their own work.

In discussing the Educreations app, the preservice teachers said they appreciated the multimedia aspects of the app (photos, drawings, and voice) and how it helped them demonstrate their understandings. This finding supports the use of the iPad as a Web 2.0 technology for publishing and commenting through Educreations (Luehmann & Frink, 2012). Other studies have discussed the potential for computing technology to be used for a variety of presentation formats that can be customized to individual student strengths and the nature of the content presented (Edelson, 2001). In particular, in subjects other than science, mathematics, and social studies, the use of the iPad and iPod devices have aided students in multimedia presentations of their understandings of content (Saine, 2012). Our study found that the iPad was also seen as a beneficial tool for creative presentations of science content understanding. Its use fully supports the Web 2.0 characteristics of "communicating in real-time" and "connecting to people and information" through document and application sharing (Luehmann & Frink, 2012).

Limitations of Study

The use of various computing devices as tools for data collection and analysis is not in itself a new finding (Edelson, 2001; Kim et al., 2007). One benefit of the iPad appears to be its instructional scaffolding potential (provision of videos and images). With our preservice teachers, the progression from direct, concrete experiences with phenomenon to the development of abstract scientific explanations became apparent over time. However, we did not collect data that would allow us to claim that the use of the iPad as a unified data collection, analysis, and communication device resulted in better science interpretations. Yet, the preservice teachers' discussions of the benefits of the iPad for multiple purposes anecdotally support the assertion that technology that allows students to collect and interpret electronic data in real-time promotes better interpretations of that data (as in Linn & Hsi, 2000).

A larger limitation of this research is that we did not investigate how the iPad helped preservice teachers develop their science content. Though many preservice teachers mentioned how rewatching videos of their vehicle's movement forged connections between their project and forces and motion science concepts, their responses did not identify which concepts or how the iPad promoted existing understanding. This is a significant limitation of the study. However, the preservice teachers' perceptions of iPad use, as students and as future teachers, revealed its potential as a learning tool for science in an inquiry-based context.

In addition to limitations to the research, we found a significant limitation in our integration of iPad technology use in our inquiry-based teaching. Specifically, the preservice teachers benefited from their use in terms of supporting their development of scientific practices in the *Framework* (NRC, 2012) and believed the iPads were beneficial as tools that helped them carry out scientific practices. However, the preservice teachers did not seem to critically explain how it facilitated the development of science content knowledge. Indeed, our preservice teachers' responses about the value of iPads were relatively superficial with respect to the underlying pedagogical issues related to their use. This relatively noncritical stance is troubling, in that within a year, these students will have their own classrooms and will be making decisions about technology integration.

Implications

Several implications from this study can have relevance for science teacher educators. As technological tools become more ubiquitous in classroom settings, teachers must expand their pedagogical content knowledge to include a critical stance about technology use. Science teacher educators must explicitly encourage preservice teachers to question how technological tools can facilitate the inclusion of the eight Practices for K-12 Science Classrooms (National Research Council, 2012).

Technology should serve as a mechanism for supporting students as they ask questions, plan and carry out investigations, analyze and interpret data, use mathematics, construct explanations, engage in argument based on evidence, and obtain and communicate information. Certainly, the devices also offer potential to help children engage in and record direct physical interactions, simulate experiences that they may not be able to have in any other way, and interact with one another. However, preservice teachers must come to understand that the true value of technology in the science classroom will only be recognized when used in conjunction with direct, hands-on experiences. Teachers must frame its use always in the service of and not as a replacement for those direct experiences.

Even in situations where technology offers clear benefits, a number of different devices are often available to do similar tasks. Indeed, with the convergence of technologies, a wide range of devices offer users the same ultimate functionality in terms of photography, web search, app manipulation, and presentation—albeit in different packages. For example, many students own smartphones that will do most of what an iPad does, including running apps and taking photos. Other capabilities of the iPad, such as word processing and access to information from web sources, are done as well as or better on a laptop or desktop computer.

What makes a tablet computer particularly useful for teaching and learning in the context of a project such as the DP is the ease with which groups of students can gather and view data using one device. That is, while the unit is entirely portable and, thus, useful for data gathering, the screen is large enough for collaborative work and discussion. Furthermore, while the tactile relationships students can have with a touchscreen is not truly hands-on, it offers a more direct mode of interacting with information and imagery than when the interface is mediated by a keyboard and mouse.

Of course, trade-offs exist with each piece of technology, and the iPad proved less useful for exchanging files, writing, and doing extensive research. Additionally, interactive white boards such as the Smartboard do not interact with iPads beyond projecting an image from its screen. While the iPad is clearly a tool for collaboration, the interface remains the relatively small screen even when connected to an interactive whiteboard. It is highly relevant to the development of preservice teachers' critical pedagogical skills that they confront and discuss both the strengths and weakness of the device for various purposes, as well as analyze the way the device shapes student interaction.

The study reported here provides only an initial investigation into the potential for iPad use within a science-specific context. Many additional questions should be addressed in future research. For example, we investigated preservice teachers' perceptions of iPad use. We did not measure learning outcomes, nor did we assess how their experiences with iPads will affect their teaching and their own students' learning once they are practicing teachers. Knowing more about whether or not the use of the iPad impacted the conceptual understanding of the science content would be beneficial. Additionally, more information is needed about which specific aspects of iPad use could prove meaningful in developing scientific understandings. While we asked preservice teachers whether they believed that they would use iPads in their future classrooms, studies investigating actual classroom use and outcomes with respect to student understanding would be informative. As teachers are identified who use the iPads as a tool for supporting inquiry-based practices, it would be instructive to develop cases of their classroom practice.

A further area of investigation should focus on the development of apps. Thousands of apps currently exist, yet many allow users only to review content and serve as the digital equivalent of flash cards (Murray & Olcese, 2011). Some apps such as Educreations and Weight and Mass show promise, but great potential exists for the development of additional apps that better utilize the capabilities of the iPad as a tool. Of primary importance in this work will be a focus on the development of apps that help students build and share knowledge rather than just absorb and repeat information.

Additionally, more work is required to develop ways of repurposing existing apps by developing approaches to their use that better serve constructivist goals. As iPads or other tablet devices become more common in classrooms of the future, the use of the tool must be shaped not by the serendipitous availability of certain apps or features.

Given the enthusiasm for the newest electronic devices in the culture at large, schools have an understandable tendency to see cutting-edge technologies as central to solving educational problems. The teacher must stay focused on the underlying goals of the classroom and each discipline and evaluate each tool in light of those goals.

While iPads and other devices will certainly find a use in science education, education researchers must make an ongoing effort to understand how and when they may be used for the promotion of scientific practices, and when they should be set aside in favor of other approaches. Ultimately, educators' thinking about the use of any technology in science classrooms must not be shaped by the production and availability of particular devices but by a progressive vision of science education, in which students create meaning from interactions with the real world and each other, engaging technology as a tool where appropriate to that task.

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Resources

Acceleration -
http://homepages.ius.edu/rwisman/Ubiquious%20Learning/html/acceleration.htm
Create-A-Graph - http://nces.ed.gov/nceskids/createagraph/default.aspx
Drainworks LT - https://itunes.apple.com/us/app/drainworks/id401437090?mt=8
Dropbox -https://www.dropbox.com
Educreations, Inc. - http://www.educreations.com
Exploriments Weight & Mass -http://www.exploriments.com/ipad/weight_mass.html
Gravity HD - http://namcobandaigames.com/ios/isaac-newtons-gravity1
iMovie - http://www.apple.com/apps/imovie/
RCB Travel: http://www.dimensiontechnics.com/rollercoaster-builder-travel-universal/

Appendix
Survey Items

Q1. Through an iPad initiative, you were able to explore concepts of forces and motion for the Design Project. In what ways do you feel that the use of technology impacted your understanding of the underlying science content?

Q2. Would you consider using iPads with your future students? Why or why not?

Q3. If you answered yes to the previous question, which Apps would you be most likely to use?

Q5. How did the use of the iPad affect your ability to learn the science content with your partners?

Q6. In what ways did the technology allow you to do things that you would not have been able to do otherwise? (Please give examples in your response.)

Q7. What aspects of using the iPads were enjoyable? Were any aspects frustrating? If so, please describe below.

Q9. Additional comments: