2020

Learning Science With Mobile Technologies: Opportunities for Enhancing Preservice Elementary Teachers' Science Conceptual Understanding

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The use of technology is increasing rapidly in our society, and classroom teachers must recognize the impact and importance of technology in the lives of their students. It is crucial that college faculty involved in teacher training design courses that integrate mobile technologies to prepare the next generation of teachers. In this study, we investigate the effectiveness of an iPad-based curriculum app, Exploring Physics, to enhance preservice elementary teachers' physics conceptual understanding in a physical science content course. Data were collected using a pre-and postPhysics Conceptual Understanding (PCU) survey and open-ended questionnaires. We found significant statistical gains in participants' (N = 73) physics conceptual understanding at the end of the course. Qualitative findings suggest that the learning experience allowed participants to experience the pedagogical affordances of mobile technologies as learners and future teachers and found themselves to be more comfortable with the idea of integrating technology into their future classrooms. The results of this study provide insights into the importance of providing preservice teachers with opportunities to experience the use of mobile technologies in their teacher preparation programs.

Mobile technologies such as tablets, iPads, smartphones, and laptops have become more popular in K–12 classrooms (Zhang, 2015). Given the accessibility and user-friendly nature of mobile devices, students have become savvier with using mobile technologies (Chow, 2015). Benefits associated with the use of mobile technologies include increased student engagement, collaboration, and access to unlimited resources beyond the information in the textbook (Reid & Ostashewski, 2011; Tessier, 2014). Despite mobile technologies being more accessible in classrooms, teachers are often reluctant to use or integrate them into their science curriculum (Ertmer & Ottenbreit-Leftwich, 2010). One of the reasons is the lack of teacher training in preservice teacher coursework on how to integrate mobile technologies in science teaching. Additionally, a limited knowledge of the pedagogical approaches for using mobile technologies in learning and teaching science leaves preservice teachers not fully prepared to use such technologies in their future classrooms (Ertmer & Ottenbreit-Leftwich, 2010; Menon et al., 2017).

Prior research suggests that preservice teachers' exposure to technology within their coursework greatly increased their confidence in integrating technology compared to preservice teachers who received no exposure or experience to use it (Abbitt & Klett, 2007). Research also suggests that teachers teach the way they were taught (Coutinho, 2007). Thus, preservice teachers must be engaged in science learning through mobile technologies in order to value the pedagogical approaches offered by mobile technologies (Gess-Newsome et al., 2003). Moreover, there is a great need for the integration of mobile technologies in science, as science reforms demand science teachers to increase their integration of technology in their teachings to better prepare their students for the 21st century (Guzey & Roehrig, 2009).

The objective of this study is to investigate the use of an innovative iPad-based physics curriculum, Exploring Physics (EP) on preservice elementary teachers' science conceptual understanding in a physics content course designed for preservice elementary teachers. The research questions investigated were: (1) How does the EP curriculum influence prospective elementary teachers' science conceptual understandings? (2) What factors about this engagement helped preservice teachers as learners and future teachers of science?

Methodology

This study was conducted in a semester-long physics content course designed for early childhood and elementary education majors at a large, midwestern university. A typical enrollment in the physics content course ranges from 20–25 preservice teachers per semester. This study took place over the course of two years (four semesters). The class met three times per week (Monday, Wednesday, and Friday) and included two class sessions of one hour and 50 minutes each (Monday and Wednesday), and one session of 50 minutes (Friday). Participants included 73 preservice teachers: 56 were elementary education majors, 12 were early childhood education majors, and five were special education majors. The majority of the participants were female (N = 68) and five were males. All participants were in the age group of 19–21 years. Regarding their year in the program, only one participant was a freshman, 49 of the participants were sophomores, nine were juniors, and only one was a senior. All participants were informed about the purposes of the research on the first day of class and a recruitment script approved by the Institutional Review Board was read. The recruitment of participants was on a voluntary basis. Each student was provided with an iPad at the beginning of the semester to use both for in-class activities and at home.

Throughout the semester, preservice teachers worked in a group of three to maximize student participation and discussions within the group. At first, the groups were arranged based on the random assignment, which allowed students of different backgrounds to interact with each other. These groups were switched at the end of each unit or about three times in a semester. After the first test, groups were arranged based on the test scores, where students with high scores were matched with students with low scores. This arrangement was made to maximize student learning outcomes, where students who grasp the concepts can help other students in the group who may find the concepts challenging.

The Exploring Physics curriculum app

The class used a program called the EP curriculum app, which was downloaded on all iPads prior to their first class. Each preservice teacher was provided with a unique user name and password, which allowed them to log in to the curriculum app and store their individual work. Within this curriculum, there are eight different e-units, which were divided into three major topics: electricity, force and motion, and energy. At the completion of each major content area, students were given an exam on the information in that content area. In addition to the three major exams, there were short quizzes every Friday and at least two group projects. Students used the EP curriculum to access the information pertaining to the content; however, any additional materials such as class PowerPoints or articles were available on Blackboard.

The EP curriculum app offers a variety of unique features, which were designed for preservice teachers to understand the content and experience the benefits of incorporating technology to teach science. Each unit consists of prelab and postlab discussions, hands-on investigations, and additional practice problems. The interactive inquiry offered by this curriculum app is unique, as information is not only presented in multiple formats, but can also be entered in multiple formats: texts, drawings, equations, graphs, and videos (Figure 1). The variety of formats available through this app was targeted to the preservice students' unique learning styles and to foster learning for all. Model-building tools and scaffolds, such as the use of questions and built-in animations, promote guided inquiry and personalized learning. Two other features provided by the app is the ability of being hybrid offline-online, which allowed students to access their work online and offline. The internet connection was only needed when students needed to download additional e-units or to submit their work to the instructor. However, students could work offline to insert their responses to the questions within the app using model-building tools. Lastly, the app featured a teacher resource guide, which offered support for teachers, including videos on how to set-up an experiment, pedagogical principles used, and common misconceptions related to each topic. The app also allowed teachers to grade and keep records of student responses in one centralized location.

Data collection

Data were collected in the beginning and the end of the semester using a survey and an open-ended questionnaire. The survey, "Physics

Conceptual Understanding" (PCU), was administered as a pre- and posttest, being composed of 20 multiple-choice questions. The questions for the PCU were chosen from the three established instruments in the field of physics education: Determining and Interpreting Resistive Electric Circuit Concepts Test (DIRECT) (Engelhardt & Beichner, 2004), Force Concept Inventory (FCI) (Hestenes et al., 1992), and the National Science Teachers Association (NSTA) PD Indexer tool, an online resource available from NSTA. The Cronbach's α value for the pre- and postPCU were 0.71 and 0.70, respectively. Qualitative data were collected via an open-ended questionnaire (Figure 2). The questionnaire consisted of questions that targeted to reveal participants' perceptions of using iPads for teaching and learning of science, and their views on learning physics using the curriculum app.

FIGURE 1

A snapshot of the tools in the Exploring Physics app.

The image below is a snapshot from the *Exploring Physics Curriculum*. The picture depicts Model-building tools embedded within the app that students can use for problem-solving.

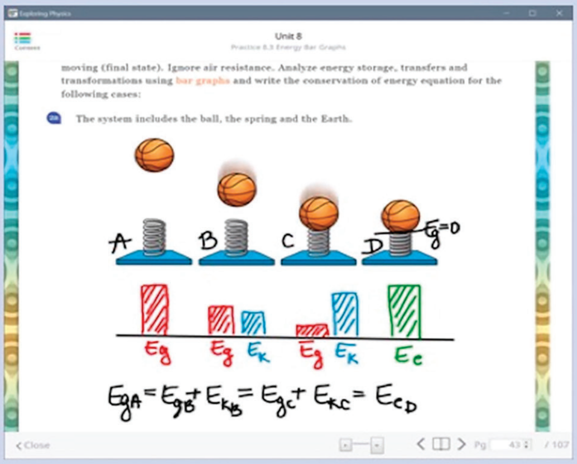


FIGURE 2

An open-ended questionnaire on the use of iPads in learning/teaching.

This open-ended questionnaire was designed to assess preservice elementary teachers' perceptions of the use of iPads for learning and teaching science, and their views about learning physics using the *Exploring Physics* curriculum in the physics content course. All responses were anonymous and were collected using the online medium via the course site.

1. Describe what you liked about using an iPad-based curriculum for the class?
2. Describe what you disliked about using an iPad-based curriculum for the class?
3. What changes could be made to improve your experiences with the *Exploring Physics* curriculum?
4. What do you see as the benefits associated with learning via iPads?
5. What do you see as the challenges associated with learning via iPads?

Data analysis

Quantitative data were analyzed using IBM SPSS 24.0. A repeated measures analysis of variance was used to examine the changes in physics conceptual understanding and technology self-efficacy pre- and postintervention. The qualitative analysis of the open-ended questionnaire was conducted using an open-coding technique to reveal the trends related to participants' views of mobile technologies and its merits and challenges associated with its use in the classroom. At first, qualitative responses were read and re-read to identify codes that represent the features of the app, as identified by participants, that were helpful for learning the concepts. The codes were grouped under the category called "learner benefits"—associated with how and in what ways the experience of learning via iPads helped participants as learners of science. Next, the data were again revisited to find codes that were associated with participants' perceptions of using iPads for future teaching, which were coded under category called "teacher benefits." This category encompassed whether and in what ways the experience of learning iPads improved participants' attitudes and/or confidence in using mobile technologies in teaching.

Results

The quantitative analysis of the results from the PCU survey indicated a significant positive change between the pre- and postintervention scores at the $p < .05$ level [F (1, 72) = 112.71, p = 0.000, η^2 = .610]. Physics conceptual understanding mean scores showed a significant positive increase from pre-test (M = 6.589, SD = 2.2038) to posttest (M = 10.548, SD = 2.7540). The partial η^2 provided the estimation on the effect size, and there was a large effect size for the mean difference between the pre- and posttest (η^2 = .610). These results provide evidence for the effectiveness of the EP curriculum in supporting participants' deeper physics conceptual understanding. The qualitative results from the open-ended questionnaire provide an understanding of the factors about this engagement, which helped preservice teachers as learners and teachers of science.

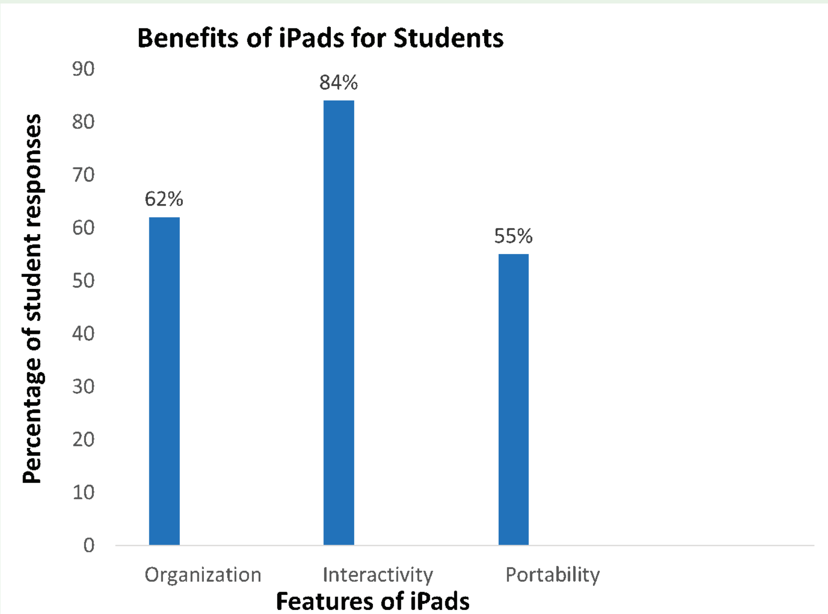
Benefits of the Exploring Physics curriculum: Learners of science

In this section, we describe the features of the app that supported participants as learners to enhance their physics conceptual understanding. The three categories in which the app benefitted the participants were: (1) organization, (2) interactive nature, and (3) portability. The open-ended questionnaire revealed that participants felt that the organization, interactive nature, and portability of the curriculum app enhanced their learning experience (Figure 3). About 47% of the participants found that the organization of the app enabled students to be able to access all relevant information in a sole location. Participants appreciated the organization of the information within the app, such as division of pre- and postlabs, reading pages and problems, as well as the writing features provided by the app, which allowed the participants to be more organized as students. Participants noted that the curriculum app, being on a mobile technology, provided more organization than traditional papers, lectures, and textbooks. For example, one participant explained, "The reading pages were especially nice because rather than digging through old papers you could swipe through an organized list rather quickly" (participant 31). Other participants also mentioned similar benefits of being organized and that all information needed for the course was easily accessible and organized into one app on a mobile device. As a student described, "I liked having all the information for the class in one compact location. It made it easier when it came time to study for the tests and quizzes" (participant 29). Another participant also noted that the app included everything needed for the class and did not require another notebook as, "all of the notes and labs were all together" (participant 7).

Approximately 64% of participants appreciated the multimedia features embedded in the curriculum app, such as simulations and videos, and mentioned that these features enhanced their conceptual understanding of the physics topics. The open-ended questionnaire revealed that the participants found that the unique features such as writing text and the whiteboard feature for making diagrams, tables, and graphing features embedded within the app truly enhanced their learning experience by making the curriculum

FIGURE 3

Survey responses on the benefits of iPads for student learning.



interactive. The easy-to-use and interactive features of the app enhanced the participants' learning experience, leaving them more "engaged" as a participant stated (participant 47). The app provided participants with unique ways of learning: "It also allowed for me to manipulate objects as if I had the science objects sitting in front of me" (participant 62). The app allowed all students to have the same engaging materials accessible to them at home. A student commented, "The videos really helped me learn more about the information and helped me understand what I read" (participant 27). With the way the app was set up, the participants were able to submerge themselves in their learning. Moreover, about 41% of the participants appreciated the portability of the iPad-based curriculum, as it made it easier to access the information whenever and wherever they needed it. Because the curriculum is designed in an app, students are able to participate in their physics conceptual learning anywhere and whenever it is convenient for them. As college students, portability is essential. By incorporating mobile technologies into course curriculums, all students were able to access the curriculum offline in their homes to complete their assignments. Students emphasized that the iPad "was a lot easier to carry around versus a textbook" (participant 21).

The iPad-based curriculum not only benefited the participants as learners in increasing their conceptual understanding of physics, but the curriculum also increased the participants' confidence in using mobile technologies as future educators.

Benefits of the Exploring Physics curriculum: Future teachers of science

In this section, we describe how some participants became cognizant on ways that the iPad-based curriculum allowed them to realize the benefits of teaching through mobile technologies. After firsthand exposure of learning through iPads and the app, participants felt more confident in their skills and abilities to use these devices appropriately and efficiently. Two categories were identified by the participants: (1) enhanced understanding of the pedagogical aspect of learning via iPads and (2) feeling up-to-date on mobile technologies. As one participant mentioned, "As a future teacher, it taught me how to deal with technology in the classroom, whether it was on how to use an iPad or how to deal with technology problems in the future" (participant 8). Another participant commented that mobile technologies made it easier for them to be able to provide variability in their instruction as future teachers: "Mobile technologies allow teachers to ensure every student's learning style and needs are being met, like those who are visual learners" (participant 40).

Many participants mentioned that the iPad-based learning experience has allowed them to become familiar with using apps and thus they feel up-to-date with the use of technology as it is prevalent in schools. As one participant mentioned, "Learning through iPads definitely gives you experience for when you become a teacher yourself. Technology is becoming more dependable in classrooms so getting the opportunity to work with it and different apps is a nice way to be introduced to it" (participant 7). Some participants were able to truly reflect on how learning through an app provided them an insight on how to keep up with modern technology. As a participant mentioned, "I will be able to teach my students about the different tools that technology has to offer and how to navigate the iPad. I think that since today's era is so technology involved, this was a good step to take to start learning through iPads. We had to get used to doing things in a new way, since this may be what we will be teaching on one day!" (participant 3). This curriculum app demonstrated a seamless integration of mobile technologies and allowed preservice teachers to access the most up-to-date information and resources via use of the app. A participant described that the iPad "allows us to learn to use technology in our classroom and be successful" (participant 15). The personal experience and consistent exposure to an iPad-based curriculum allowed the participants to increase their pedagogical knowledge on mobile technology integration and become more confident in their abilities, as future teachers, to use technology efficiently in their future classrooms.

Discussions and implications

This course and research were situated on the idea that if future teachers experience learning science with explicit integration of mobile technologies, they are more likely to use such technologies in their own teaching. Specifically, we investigated (1) how the EP curriculum influences prospective elementary teachers' physics conceptual understandings and (2) how this this engagement helped preservice teachers as learners and teachers of science. Our statistical evidence and the partial eta squared (η^2) analysis suggests a large effect size for the positive changes in physics conceptual understanding. Prior to this study there was only a small amount of evidence on mobile technologies, such as iPads, and their effectiveness in increasing preservice teachers' understandings of the content in a science content course. In our study, increase in mean test scores (pre- versus postintervention) as well as qualitative evidence support the fact that the iPad-based EP curriculum helped increase participants' conceptual understanding of physics as well as their confidence with using such technologies in teaching. The qualitative analysis was based on the participants' perspectives as both learners and future teachers of science.

It appeared that regardless of whether or not participants had experienced learning science using iPads, they seemed to benefit by participating in this novel approach to learning science because the iPad-based curriculum offered many affordances for them to develop their conceptual base. As students, the EP curriculum enhanced the participants' learning by providing a curriculum that was organized, interactive, and portable through the mobile technology of the iPad. Students in this study appreciated that the EP curriculum offered organization to the course, as everything needed for the EP curriculum could be found on one device. The interactive nature of mobile technologies was another factor of the iPad, which enhanced the participants' learning. Along with its portability, the easy-to-use intuitive functions increased the usability and convenience of the iPad (Rossing et al., 2011). Mobile technologies allow students with different learning styles to take ownership of their learning as it enables them to easily create and use multiple means of representation for their learning, such as videos and graphs (Khoo & Otrel-Cass, 2017).

It is important to not only explore the perspective of students using mobile technologies in the classroom, but also to explore the perspectives of teachers (Pegrum et al., 2013). As preservice teachers, the participants noted that the use of mobile technologies was beneficial to them because they were exposed through learning via iPads on a daily basis. In order for teachers to be challenged to adopt new ways of learning for their students, it is critical that future teachers are provided with evidence that mobile technologies can support and positively impact students' learning (Ertmer & Otternbreit-Leftwich, 2010). The best way to provide preservice teachers with solid evidence is exposing them to learning through mobile technologies long term, so they can experience successful mobile technology integration and the benefits firsthand (Abbitt & Klett, 2007). Another benefit of using mobile technologies that the participants noted as preservice teachers is the readily accessible up-to-date information. Teachers are able to stay updated on relevant and accurate information in order to support their students, and students are also able to embrace the investigative nature of science by being able to explore information via the Internet (Tessier, 2014).

Although we were able to analyze the perspective of the participants on how mobile technologies are beneficial to teachers, fewer participants discussed the teacher benefits. Out of the 73 participants, only 25 participants explicitly provided us with their insights on the pedagogical advantages of the iPad-based curriculum. The smaller number of participants who described the benefits of mobile technologies presented to teachers makes sense considering that this was a content course. Most of the participants were able to fully understand the benefits of iPads and other mobile technologies as students. Nevertheless, the fact that these are future teachers, this exposure allowed them to gain a unique and needed outlook on how to integrate mobile technologies in their future classrooms. Along with many other researchers, we recommend ongoing professional development as a way to explicitly focus on helping teachers become experts in effective integration of mobile technologies in the classroom (Gess-Newsome, et al., 2003; Guzey & Roehrig, 2009; Chow, 2015).

Research-based professional development can provide support and enhance teachers' knowledge on educational technologies, as well as provide teachers with the ability and tools to implement and design unique experiences for their students through the support of mobile technologies (Mouza, 2009). It is essential that professional development and pedagogical support for teachers and technology is ongoing, as one-time trainings have not been evidentially effective in supporting the efficient integration of mobile technologies in classrooms (Haddad & Draxler, 2002). While professional development trainings can be beneficial for in-service teachers as well, it would be ideal for preservice teachers to receive experiences with mobile technologies in their teacher preparation programs. For example, there have been various strategies for teacher preparation programs to include instruction on technology integration. One such strategy is blended courses, which integrate technologies within the course itself (Gronseth et al., 2010). Teachers teach how they learn; if university preservice programs are not providing sufficient exposure on the use of mobile technology integration in science, it is likely that preservice teachers would be less prepared to implement iPads in their future classrooms, which is in high demand.

Conclusion

This study highlights the importance of designing preservice science content courses that use mobile, technology-based curriculums for improving conceptual understanding of science while demonstrating the pedagogical approaches of using mobile technologies that are applicable in students' future teaching. The study has implications for future research in the area of the use of mobile technologies in preservice teacher training. While our quantitative evidence supports the idea that our participants were able to enhance and gain physics conceptual understanding through the use of the iPad-based curriculum, we did not investigate how our statistical evidence may compare to the gain of conceptual understanding of preservice teachers learning in a traditional-style or nondigital course. More studies are needed to get a closer look on how learning via the use of mobile technologies translates into preservice teachers' practices—whether or not they use such technologies in their field teaching. ■

Acknowledgment

Financial support: This work was supported by the National Science Foundation grants NSF-DUE 0928924 and NSF-IIP 1608624.

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