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Deepika Menon

Meera Chandrasekhar

Dorina Kosztin

Douglas Steinhoff

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Deepika Menon,[1] Meera Chandrasekhar,[2]
Dorina Kosztin,[2] and Douglas C. Steinhoff[2]

1 Department of Physics, Astronomy and Geosciences, Towson University, Towson, Maryland
2 Department of Physics and Astronomy, University of Missouri, Columbia, Missouri

Correspondence — Deepika Menon, *email* dmenon@unl.edu

ORCID Deepika Menon http://orcid.org/0000-0002-8652-7019

Abstract

The growing popularity of mobile technologies in educational settings, from grade schools through college, has prompted science educators to prepare preservice teachers to successfully integrate technology into science teaching. This mixed-methods study explores the effectiveness of a mobile technology-based physics curriculum, Exploring Physics, on preservice elementary teachers' technology self-efficacy. Participants included 67 preservice elementary teachers enrolled in a specialized physics content course at a large public university in the United States. The experimental group

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(N = 34) used the Exploring Physics curriculum on iPads, and the comparison group (N = 33) used a hardcopy version of a similar curriculum. Data sources included a technology self-efficacy survey administered as pre- and posttests, focus group and individual interviews with 24 participants at two time points, weekly classroom observations, and artifacts. Data analyses included repeated measures analysis of variance and posthoc t tests with Bonferroni adjustments and grounded theory techniques. The results showed significant positive changes in the experimental group participants' technology self-efficacy. In contrast, there was a significant decrease in the comparison group participants' technology self-efficacy. Several affordances of the curriculum assisted the experimental group participants in developing an appreciation for using mobile technologies in science teaching. Implications for preservice teacher preparation for technology integration in science teaching are discussed.

Keywords: mobile technologies, preservice teacher training, technology self-efficacy

1 Introduction

Digital technologies are increasingly becoming part of daily life, including for young children (Goggin, 2012; Pegrum, Howitt, & Striepe, 2013; Zhang, 2015). Ever since the advent of mobile technologies, such as smartphones, iPads, and tablets, and their growing popularity in homes, more children, including preschoolers, are becoming addicted to interactive media and gameplay at an early age (Couse & Chen, 2010). In a recent national survey conducted in the United States, 53% of elementary school students reported regular use of smartphones (Poll, 2015), 95% of families with young children (age eight and under) owned smartphones and 98% of homes with children of the same age group (age 8 and under) possessed mobile devices (Common Sense Media, 2017). Moreover, school districts are investing in providing mobile devices to K-12 students with a 1:1 model of one device per student (Bebell & O'Dwyer, 2010; Crook, Sharma, Wilson, & Muller, 2013; Looi et al., 2010; Molner, 2015). Because of this explosion in the use of mobile devices, science education researchers and practitioners are continually finding better ways to make use of mobile technologies in educational contexts from grade school to college settings (Wilson, Goodman, Bradbury, & Gross, 2013).

While iPads and tablets are becoming part of elementary teaching, a larger question to ask is, are elementary teachers trained to teach science using mobile technologies? While teachers may have access to mobile technologies at home or school, they continuously struggle to meaningfully integrate mobile technologies into their instructional practices (Ertmer, 2005; Hew & Brush, 2007). The literature has documented some of the challenges associated with teachers' use of mobile technologies, such as the lack of teacher training; the scarcity of appropriate activities or curricula that integrate mobile technologies, such as iPads and tablets, into science teaching (Crook et al., 2013; Pegrum et al., 2013; Wilson et al., 2013) and personal abilities, such as lack of confidence in using technology (Wang, Ertmer, & Newby, 2004).

A recent report by the National Education Technology Plan (U.S. Department of Education, 2010) recommended the incorporation of mobile technologies into education for future science educators and practitioners to leverage and facilitate student learning. Furthermore, the report called for "efforts to ensure that all students and educators have access to mobile devices both in and out of school to prepare them to be active, creative, knowledgeable and ethical participants in our globally networked society" (p. 9). Such efforts emphasize that science educators should institute substantial changes in preservice training programs to increase teachers' proficiency in learning and teaching science using mobile technologies (O'Bannon & Thomas, 2015). Teachers frequently teach in the ways that they have been taught (Pope, Hare, & Howardy, 2002). Thus, science educators who advocate for increased incorporation of mobile technology argue that teacher preparation courses should provide models for successful technology integration that are consistent with the expectations of how teachers will teach in their future classrooms (Brown et al., 2016; Liu et al., 2016; Menon, Chandrasekhar, Kosztin & Steinhoff, 2017; Rehmat & Bailey, 2014).

Past studies have noted that the pre-existing beliefs and perceptions about technology integration that teachers hold during their preparation years influence both the frequency and level of technology use during student teaching (Bell, Maeng, & Binns, 2013; Wang et al., 2004) and their future teaching practices (Chen, 2010; Liu et al., 2016; Piper, 2003). Evidently, teachers' self-efficacy beliefs regarding technology integration have been known to predict their intentions to use technology (Anderson & Maninger, 2007; Oliver & Shapiro, 1993; Wang et al., 2004). Extensive empirical research has documented the critical links between preservice teachers' technology self-efficacy and their intentions to integrate technology into their future classrooms (Anderson, Groulx, & Maninger, 2011; Banas & York, 2014), attitudes toward technology integration (Allsopp, McHatton, & Cranston-Gingras, 2009; Rehmat & Bailey, 2014), and technology acceptance and satisfaction (Holden & Rada, 2011).

While the extant literature has addressed preservice teachers' technology self-efficacy, there is limited research on how preservice teachers learn science via mobile devices, such as smartphones, iPads, and tablets and, consequently, how their technology self-efficacy related to mobile technologies is developed. This study addresses the gap by exploring the ways in which preservice elementary teachers' long-term engagement in learning science via mobile devices supports their technology self-efficacy beliefs regarding teaching science using mobile technologies. Most studies on mobile learning have focused on using mobile devices for a *single* project, activity, or field experiment (Looi et al., 2014; Wu et al., 2012). However, findings from these studies have not shed much light on *how* and under *what* conditions these short-term interventions are effective in terms of bringing positive changes to preservice teachers' perceptions of teaching and learning science using mobile technologies. As noted by Looi et al. (2014), long-term intervention studies are needed to explore the effects of mobile learning on teacher beliefs and practices.

Furthermore, importantly, a majority of the research studies exploring preservice teachers' beliefs and perceptions about technology integration have been conducted within the context of science methods or educational technology courses (Anderson & Maninger, 2007; Banas & York, 2014; Rehmat & Bailey, 2014; Wilson et al., 2013). Given that science content courses are an integral part of preservice teacher training, beliefs about teaching science using mobile technologies are likely to be influenced by science learning experiences, specifically those with the use of mobile technologies (iPads, tablets, and smart phones). This study is unique in exploring the changes in preservice teachers' technology self-efficacy beliefs as they engage in learning science using *mobile* devices (iPads, tablets, and smart phones) in a semester-long science content course.

2 Focus of this Research

This study addresses two gaps in the literature by exploring (a) how preservice teachers' technology self-efficacy beliefs are impacted by learning science via an innovative iPad-based curriculum, Exploring Physics (http://www.exploringphysics.com/), in a semester-long specialized physics content course and (b) what affordances and learning experiences within a mobile technology-supported learning environment preservice teachers find beneficial for their own understandings of science and for future science teaching. We compared technology self-efficacy beliefs between preservice elementary teachers' who were learning physics with the Exploring Physics curriculum on iPads (experimental group) and those who used a hard-copy version of a curriculum that was similar in scope and sequence (comparison group). The curriculum for both groups included hands-on inquiry- and modeling-based labs, in-class discussion, practice problems, and readings. Both groups used a traditional whiteboard and a Smartboard. The comparison group used simulations from other sources, such as PhET (https://phet.colorado.edu/en/simulations), in class on desktop computers; however, the experimental group had 1:1 exposure with iPads on a routine basis during regular class meetings, and simulations and animations were built into the curriculum application (hereafter, app). While the PhET simulations were the same for both groups, the app provided access to many more animations of science concepts that were not part of the hard-copy curriculum. The specific research questions explored in the study were as follows:

1. How does the Exploring Physics curriculum influence preservice teachers' technology self-efficacy beliefs compared to those of preservice teachers taught using a hard-copy version of a similar curriculum?
2. What affordances of the Exploring Physics curriculum support preservice teachers' technology self-efficacy beliefs regarding the use of mobile technologies in their future science teaching?
3. What are preservice teachers' persistent concerns regarding the use of mobile technologies in their future science teaching?

Importantly, we purposely did not investigate or compare student learning gains between the experimental and comparison groups. It is well-known that hands-on learning is an effective pedagogical approach for learning science content (Bleicher & Lindgren, 2005; Rice & Roychoudhury, 2003); therefore, it was highly likely that preservice teachers from both groups would benefit in terms of the science content knowledge. We were more interested in exploring the pedagogical possibilities afforded by the Exploring Physics curriculum and the factors that could support preservice teachers' technology self-efficacy beliefs in a science content course. Past research has yielded extensive empirical evidence supporting the use of technology in teacher preparation courses, which in turn has been linked with preservice teachers' intentions to use similar technologies in their future classrooms (O'Bannon & Thomas, 2015; Rehmat & Bailey, 2014). Therefore, we contend that positive experiences of learning science using iPads on a routine basis will likely influence preservice teachers' perceptions and beliefs regarding the integration of mobile technologies into their future science teaching.

3 Conceptualizing Mobile Learning

With the growing interest in mobile technologies in science education, there have been varied opinions on the conceptualization and definition of "mobile learning," its position in formal and informal educational settings, and the affordances and benefits associated with its use in higher education (Churchill, Fox, & King, 2012; El-Hussein & Cronje, 2010; Rossing, Miller, Cecil, & Stamper, 2012; Traxler, 2009). Kinash (2011) defined mobile learning as a "portable process of teaching using internet-connected devices such as laptops, tablets, and smartphones" (p. 56). The extant literature on mobile technology has identified affordances of mobile technology to include the mobility of learners and devices (Brand et al., 2010; El-Hussein & Cronje, 2010), flexibility (Jennings, Anderson, Dorset, & Mitchell, 2010; Liu, Navarrete, & Wivagg, 2014), easy accessibility (Keskin & Metcalf, 2011), and mobile devices' low cost and light weight, unlike laptops and netbooks (Brand et al., 2011; Jennings et al., 2010). Researchers claim that mobile technologies have educational benefits that support student learning in many ways, such as learning that can happen *anytime–anywhere–everywhere* (Franklin, 2011; Quinn, 2000; Seppälä & Alamäki, 2003), increased student engagement (Brand & Kinash, 2010), motivation (Chu, Hwang, Tsai, & Tseng, 2010), student communication and collaboration (Liu et al., 2014; Rossing et al., 2012), and personalized, interactive, and self-directed learning (Looi et al., 2010).

While the benefits and significance of mobile technologies in education have been recognized, conceptual frameworks and models to understand the theoretical meaning of mobile learning are also needed. The impetus for developing conceptual frameworks for mobile technologies was to support instructional designers and teachers in designing authentic mobile teaching and learning experiences (Hsu, & Ching, 2015; Park, 2011). Koole (2009) provided a framework, The Framework for the Rational Analysis of Mobile Education (FRAME), for understanding mobile learning in a broader sense. The framework ranges from defining guiding principles for designing materials or activities for mobile learning experiences to understand *how* learners perceive the benefits of mobile learning. The FRAME model is situated within the personal and sociocultural aspects of learning, where the learner interacts with both physical and virtual environments, that is, with "people, information, or systems" (p. 26).

The model utilizes key principles from three fundamental theories to conceptualize mobile learning: (a) Vygotsky's sociocultural theory of learning, (b) activity theory, and (c) social constructivism. A common theme that runs across the three theories is the interaction between individual and social environments within a social setting. From the perspective of activity theory, any activity (learning) is influenced by the sociocultural context that is mediated by pedagogical tools available for use (Engeström, 1999). Mobile learning utilizes mobile devices as pedagogical tools, which serve as active components for both personalized learning and learning via social interaction within a classroom context. On the one hand, mobile devices can help learners connect with other learners and other experts in the field (social aspect), and on the other hand, learners can choose to work within their own personal spaces (personal aspect) while having access to internet and web resources, such as video tutorials (Koole, 2009).

The FRAME model also utilizes principles of Vygotsky's sociocultural theory and social constructivism that emphasize learning via social negotiation between individuals (Vygotsky, 1978). In the context of educational practice, both the social interactions involved in collaborative activities and socially accepted cultural norms and expectations greatly influence student learning (Atwater, 1996; Shepardson, 1999). In mobile learning, exchange of information, interaction, and communication may occur between learners who belong to unique cultural backgrounds. In a mobile learning setting, learners are engaged in meaningful learning that leads to the construction of knowledge through *self-discovery* through various types of interactions to construct knowledge. These interactions could be with the materials and content available via the use of mobile devices, such as ebooks, videos, and simulations; other learners in a similar physical or virtual setting; the instructor; or a larger learning community (Moore, 1989). All of the above interactions suggest the significance of Vygotsky's (1978) *zone of proximal development*—the gap between what learners already know (which is grounded within social and cultural beliefs) and the modeling and scaffolding instructors can provide for successful mobile learning.

According to Koole (2009), mobile learning is determined by the interaction of three factors: (a) the device aspect (the technical and functional aspects of a mobile device), (b) learner aspect (including his or her prior knowledge, emotions, and motivation), and (c) social aspect (social interaction and communication). The FRAME model shaped our vision of the conceptualization of mobile learning, framing of the research study, and development of the Exploring Physics curriculum. For the purposes of this study, we utilized and explored the unique contribution of each of the three aspects (device, learner, and social aspects) as affordances of mobile learning and thus adapted a simplified version of the model. The graphical representation of our framework is illustrated in **Figure 1**. The three aspects (device, learner, and social aspects) represent the core components of the framework. The dotted lines between the three interrelated aspects indicate mobile learning as a product of the interplay between them, unlike Koole's framework. Each of the components is discussed in detail below concerning the design elements of the Exploring Physics iPad-based curriculum.

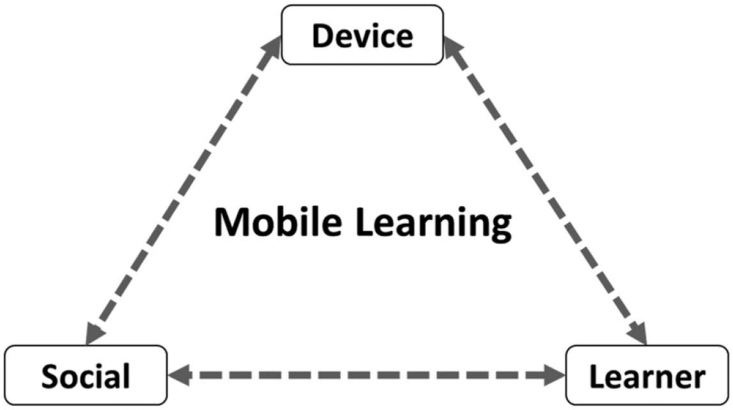


Figure 1 Graphical representation of mobile learning; adapted from Koole (2009)

3.1 Device aspect

The device aspect features include the physical, technical, and usability aspects of a mobile device. The design features are central to providing cognitive learning tasks that are appropriate for personalized learning (Looi et al., 2010) and maintaining "high physical and psychological comfort levels" (Koole, 2009). The mobile device used at the time of this study was the iPad with the iOS 8.0 operating system. The Exploring Physics curriculum (Exploring Physics, Limited Liability Company) is available as a hybrid online–offline iPad app for multiple platforms (iOS, Android, PC/Mac). At the time of the study, other platforms and system requirements for the app included Android 4.4 (Kitkat or latest available), Windows 7 (or latest available), and Mac OSX 10.7 (or latest available). In addition to affordances such as portability and accessibility, the organization of the information within the app allowed quick access to lessons, activities, experiments, and learning resources through digital books on specific topics, such as electricity. The app also has a support system for instructors with teacher guides that include expert movies on experimental setups and lab analysis, resources on the pedagogy used, and common misconceptions associated with the topic. The teacher portal allows quick access to student submissions, grading, and returning assignments to students. **Table 1** summarizes the design features pertaining to the device aspect.

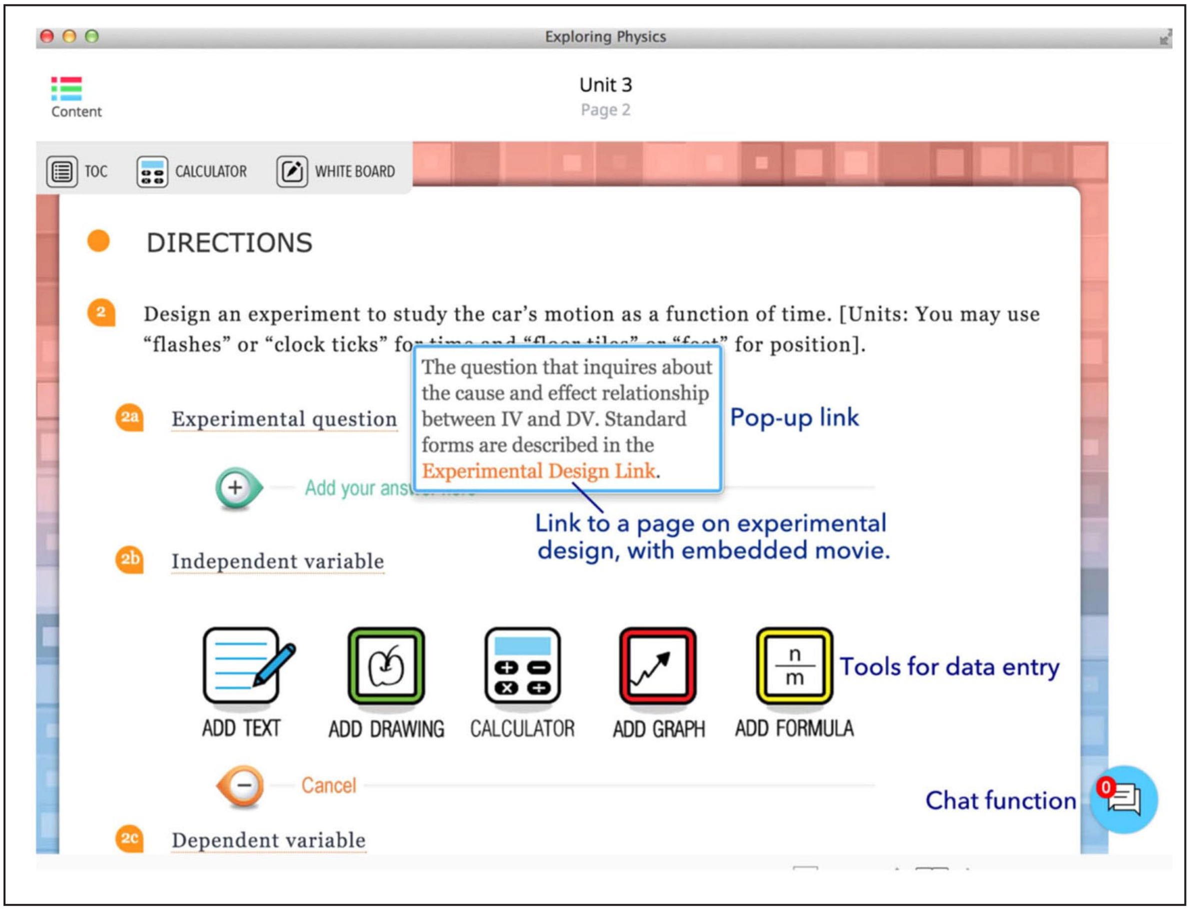
Table 1 Design features of the exploring physics curriculum

Device aspect	***Learner aspect***	***Social aspect***
Portability and accessibility	High interactivity	Communication (student-to-student and instructor-to-student)
Information storage	Model-building tools	Learning communities
Appearance (multiple representations)	Scaffolds (reference tips, reading pages)	
Organization of information/navigation	Built-in videos, animations and simulations	

3.2 Learner aspect

The second element of the framework, the learner aspect, describes a learner's motivation and willingness to adapt to new information, affective states related to performing new tasks, and ability to retain information longer (Koole, 2009). Ertmer et al. (2006) found that *intrinsic* factors such as beliefs, confidence, and commitment, which take into account the *learner aspect*, had a stronger influence on teachers' technology use than *extrinsic* factors, such as access to technology and support (*device aspect*). This notion was particularly important for our study because preservice teachers' experiences while learning through the app may influence their future decisions regarding technology in science teaching.

Several affordances of the app are tailored to support student learning in a variety of ways (see Table 1). The app, which combines workbook, laboratory book, and textbook content, promotes high interactivity, student engagement, and students' deeper understandings of physical science topics aligned with K-12 curricula using inquiry-and-modeling-based pedagogical approaches. The app consists of eight eUnits on topics such as electricity, force and motion, and energy. Each unit has labs, practice problems, and reading pages that are sequenced for spiral learning. Each lab is structured with a prelab discussion in which students interact with hands-on materials. Students are prompted to make predictions based on their observations, and they design and conduct experiments using standard experimental



Design an experiment to study the car’s motion as a function of time. [Units: You may use “flashes” or “clock ticks” for time and “floor tiles” or “feet” for position].

The question that inquires about the cause and effect relationship between IV and DV. Standard forms are described in the Experimental Design Link.

Link to a page on experimental design, with embedded movie.

Figure 2 Screenshot of the tools and scaffolds within the app.

design techniques (see **Figure 2**). Students complete a postlab discussion in which they analyze the obtained experimental data and construct a conceptual or mathematical model of the phenomenon. Labs are designed with guiding questions but not cookbook-style instructions. Within the app, students enter data using *model-building tools* to draw diagrams, make graphs, add texts, create data tables, and write equations for problem solving. The app includes *scaffolds* in the form of quick reference tips, linked reference pages, and in-unit reading pages. Reading pages include videos of sample problems solutions. Built-in animations and simulations provide visual stimulation for personalized learning. The app also allows electronic submission of assignments to the instructor, who can grade them electronically and return them to students online.

3.3 Social aspect

The third essential element in mobile learning is the *social aspect*, which focuses on social interaction and communication (Koole, 2009). Social interaction in mobile learning can be physical or virtual to enable communication and interaction between multiple learners with similar goals. The literature on the social construction of knowledge posits that meaningful learning takes place in social contexts (Oxford, 1997; Vygotsky, 1978). Researchers have suggested that new technologies such as iPads and tablets can support the social construction of knowledge, collaborative learning and interaction between learners, as well as between learners and instructors (Enriquez, 2010; Rossing et al., 2012; Shuler, Hutchins, & LaShell, 2010), and facilitate student learning (de Winter, Winterbottom, & Wilson, 2010). Concluding that social interaction is a key element of mobile learning, the curriculum app features were designed to foster such interactions (see Table 1). The app interface features a "sounding board" to facilitate student-to-student and instructor-to-student communication. Students can post their queries and comments to the sounding board for anyone to view and respond. The curriculum includes several hands-on activities for students to perform in small and large groups in class as well as group homework assignments. The app features a built-in "whiteboard" for students to share their ideas in a relaxed environment.

4 Theoretical Framework

4.1 Technology self-efficacy

This study is grounded in the self-efficacy construct, which was first conceptualized by Bandura (1977) to assess individuals' abilities to perform actions they believe could lead to desired outcomes. Researchers have recognized science self-efficacy as an influential construct in science teaching (Appleton & Kindt, 2002; Enochs & Riggs, 1990; Ramey-Gassert & Shroyer, 1992). Studies on teacher self-efficacy have suggested that highly efficacious teachers are motivated to teach and prepared to hold themselves accountable to their students (Appleton & Kindt, 2002; Ramey-Gassert & Shroyer, 1992). Self-efficacy beliefs play a crucial role in teachers' decisions regarding all aspects of classroom teaching, which ultimately influences student learning (Gunning & Mensah, 2011). Because self-efficacy beliefs are an influential factor in teachers' decision-making processes, we contend that highly efficacious teachers are more willing to integrate new technologies, including mobile technologies, into science teaching.

For the purposes of this study, the term "technology self-efficacy" refers to (a) the beliefs that shape teachers' abilities to make decisions regarding the integration of new technologies, such as mobile technologies, into classroom science teaching and (b) teachers' beliefs that their science teaching using new technologies will enhance student learning (adapted from Bandura, 1977). In general, studies have found that teachers' technology self-efficacy influences their motivation to use computers in their teaching (Niederhauser & Stoddart, 2001, Pope et al. 2002). Evidence indicates strong connections between teachers' technology self-efficacy and their willingness to integrate technology into their teaching practices (Anderson & Maninger, 2007; Lumpe, & Chambers, 2001). Liu et al. (2016) investigated K-12 teachers' comfort level with and perceptions of the use of iPads and found that teachers' perceptions of the importance of mobile technology were more positive after 1 year of implementation of iPads in their classrooms. The findings also suggested that among the teachers surveyed, elementary teachers were more comfortable with using iPads than high school teachers.

4.2 Preservice teachers and technology-related beliefs

Several studies have explored technology self-efficacy beliefs within the context of preservice science methods or educational technology courses. Past studies report that vicarious learning experiences such as exposing preservice teachers to exemplary models of classroom teaching using the VisionQuest CD-ROM increased preservice teachers' confidence and self-efficacy regarding technology integration (Ertmer et al., 2003; Wang et al., 2004). Knowledge about technology itself, in addition to knowledge about *how* to use and teach with technology, also influences teacher beliefs and their intentions to use technology (DeCoito & Richardson, 2018) and can result in increased integration of such technologies in classrooms (Bell et al., 2013; Liu et al., 2016). Hernández-Ramos (2005) reported that exposure to technology in teacher preparation programs and increased knowledge of software applications were key factors in supporting K-12 teachers' positive views regarding the use of technology. In another study conducted by Bell et al. (2013), preservice science teachers enrolled in a master's teaching program benefited from a five-course sequence that integrated knowledge about technology and instructor modeling of how to incorporate technologies such as digital images, videos, animations, and simulations in teaching science content. Similar results were found from a study conducted by Rehmat and Bailey (2014), in which preservice elementary teachers enrolled in a science methods course were exposed to modeling and explicit instruction on technology integration in science, which facilitated positive views of and attitudes toward technology integration and increased technology integration in their science lesson plans.

In the context of mobile learning, a few studies have claimed similar links between preservice teachers' acceptance and use of mobile technologies (iPads) and beliefs about technology integration (Brown, Englehardt, & Mathers, 2016; Mourlam & Montgomery, 2015). It has been argued that a wide range of mediating factors shape one's willingness or unwillingness to accept technology (Venkatesh, Morris, Davis, & Davis, 2003). In a recent study, 245 preservice teachers were surveyed to examine their perceptions of the use of mobile phones in the classroom (O'Bannon & Thomas, 2015). A majority of preservice teachers supported the use of mobile phones and believed that various functions/features of mobile phones (access to the internet and educational apps) would be beneficial for increasing student engagement. In a study by Brown et al. (2016), preservice elementary teachers' use of iPads in their field placements influenced their beliefs and conceptualizations regarding the integration of iPads into their future teaching. The findings from this study are interesting because they show that, despite being appreciative of the iPad apps, preservice teachers held doubts regarding the gaming aspect of the apps and its connections to student learning. Similar results were reported in a study conducted by Mourlam and Montgomery (2015), which investigated preservice teachers' beliefs about technology integration as they used iPads during field experiences. While the integration of iPads varied among preservice teachers, teachers' philosophical stances was a strong determining factor for changing their instructional approaches.

Using Koole's framework, this study investigates a range of factors in three distinct yet related categories: the device, learner, and social aspects. We contend that each of the factors is essential for the development of preservice teachers' technology self-efficacy. We designed the study to acknowledge and draw on the relationship between Koole's framework and the construct of technology self-efficacy within the context of preservice teachers' experiences in content courses because their experiences of learning science using mobile technologies may impact their technology self-efficacy. For instance, access to appropriate technology, in addition to the availability of hardware and software (device aspect), allows preservice teachers to explore the affordances and constraints of a technological tool (Tondeur, Valcke, & van Braak, 2008). Studies have further claimed that mobile technology extends the learning environment for learners (learner aspect), for instance, through connection via social networks (social aspect), which "opens up opportunities for students to do socially mediated knowledge-building" (Looi et al., 2014, p. 102).

5 Methodology

5.1 Design

This mixed-methods study compared changes in technology self-efficacy between a group of preservice teachers who participated in a mobile technology-based intervention and a group taught using a traditional printed workbook. The study approach incorporated common philosophical elements of both quantitative and qualitative research paradigms. Using a mixed-methods approach was well suited for this study, as such an approach provides a more comprehensive understanding of the research problem and avoids potential biases of using a single method (Denscombe, 2008; Morse & Niehaus, 2009). Specifically, both deductive and inductive approaches (Plano Clark & Creswell, 2008) were used to guide the study design, data collection, and analysis. Quantitative results were used to document the changes in technology self-efficacy, while qualitative results provided an understanding of *what* factors influenced preservice teachers' perceptions about integrating mobile technologies into science teaching and *how* they did so.

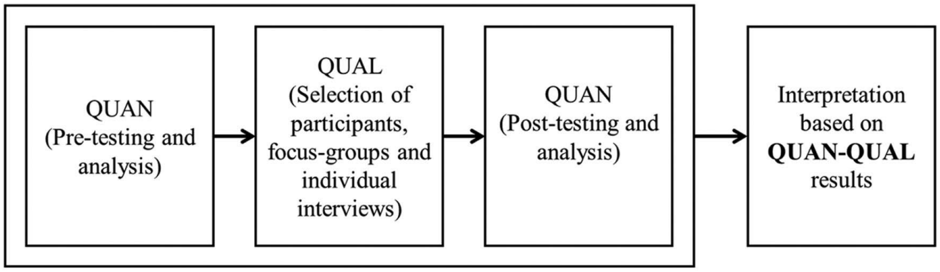


Figure 3 Phases of the mixed-methods study design

The mixed-methods research design proceeded in three sequential phases: (a) an initial quantitative phase at the beginning of the semester, which involved preadministration of the technology self-efficacy survey, (b) a qualitative phase during the semester, and (c) a final quantitative phase at the end of the semester that involved the post-administration of the survey. The initial quantitative phase involved collecting quantitative data, which further informed the selection of participants for the qualitative data collection. The qualitative phase allowed in-depth exploration of participants' beliefs and experiences with learning science using mobile technologies. The final quantitative phase involved collecting quantitative data to investigate changes in participants' technology self-efficacy beliefs. The design of this study is presented in **Figure 3**. The details of the three phases are provided in the subsequent sections.

5.2 Instructional sequence for the Exploring Physics app and the hard-copy workbook

In this section, we describe a typical instructional sequence for a science concept, and we compare the scaffolds available in the digital Exploring Physics app versus the hard-copy workbook. Below, we describe one lesson in which students learn about electrical current in series circuits. This lesson is taught after students have learned about complete one-bulb circuits, contact points, conductors, and insulators, and they have deduced that the electrical current flows in one specific direction in a circuit (from the negative end of a battery through the circuit to the positive end of the battery for the electron current). The next two questions that arise are (a) whether the current in a single-loop circuit is the same throughout the loop and (b) whether the current is the same, less or more in a two-bulb series circuit than in a one-bulb circuit (all the bulbs are similar, and the batteries in both circuits are similar). These two questions are tied to two common misconceptions: (a) that the current within a circuit decreases after going through a bulb and (b) that the current in a circuit is determined by the battery alone, and thus, a two-bulb circuit will have the same current as a one-bulb circuit. These questions and misconceptions are addressed in an activity titled *Current in Series Circuits Lab*. This lab has two goals: (a) to have students construct a pictorial mental model of the current in a circuit (the flow of electrons, where the flow rate stays constant throughout the loop in a one-loop circuit) and (b) to have students construct a semiquantitative mental model that compares the current flow in a one-bulb versus a two-bulb series circuit. **Table 2** illustrates the sequence of activities in the hard-copy workbook and the Exploring Physics app.

We note that the activity instructions are similar in both the hard-copy workbook and the app, but the scaffolds are slightly different. There are several just-in-time scaffolds in the app, such as pop-up definitions and hyperlinks, which do not exist in the hard-copy workbook. Furthermore, while the verbal descriptions in both versions are similar, the hard-copy workbook has relevant “flat” images, while the app has animations or movies that support the development of the concept. Long verbal descriptions, such as how to measure current using a multimeter, are embedded as hyperlinks that are made available repeatedly in the app, whereas in the hard-copy workbook, such descriptions are made available only the first time they are needed and in a reference page at the back of the book.

5.3 Research context and participants

This study was conducted in a specialized elementary physics content course at a large public university. The term “specialized science content course” refers to science content courses that are specifically designed for preservice elementary teachers and that integrate the understanding of science concepts with the pedagogical models advocated by national reform efforts (Crowther & Bonnstetter, 1997). These specialized science content courses are highly recommended

Table 2 Description of the current in series circuits lab as presented in the hard-copy workbook and in the Exploring Physics app

Lesson instructions	Hard-copy workbook	Exploring Physics app
Prelab: (1) Discuss a hypothetical student's electron flow concept. (2) Predict the differences between a two-bulb series and a one-bulb circuit. (3) Discuss measurable factors	Diagrams and space to record responses	Diagrams; text, drawing, and graphing tools to record responses; pop-up definitions
Lab: Build one- and two-bulb-series circuits with bulbs woven into plastic canvas	Diagram	Animated diagram on threading bulbs into plastic canvas
Lab: Predict the current at several points in one-bulb and two-bulb circuits	Diagram	Diagram; drawing tool to record responses
Lab: Learn to use a multimeter to measure the current in a circuit	Written instructions; detailed instructions at the end of the workbook	Written and verbal instructions; hyperlink to a page with instructions, unit conversions, and a movie
Lab: Use a multimeter to measure the current at several points in the circuit	Diagram and space to record measurements	Diagram; text, drawing, and graphing tools to record measurements
Lab: Questions about comparing measurements and connecting the brightness of bulb and the current	Space to record responses	Text, drawing, and graphing tools to record responses
Lab: Graph the current in a circuit versus the position of measurement; answer follow-up questions	Space to record responses	Text, drawing, and graphing tools to record responses
Postlab: Answer concept extension questions, for example, brightness of bulbs when more bulbs are added in the series, what happens if one bulb is removed	Space to record responses	Text, drawing, and graphing tools to record responses
Reading Page: Make a connection between the electron flow rate and current; identify the difference between the flow of water and electron flow	Written description	Written and verbal descriptions, pop-up definitions, and animations
Reading Page: Apply series circuits and circuit breakers	Written description and images	Verbal description, images, and a hyperlink with animations
Reading Page: Read about how current flows in a circuit (random motion of electrons, drift speed)	Written description; drift speed and calculations written sequentially	Verbal description, pop-up definitions, animation of electrons in a wire with and without current, hyperlink to a calculation of drift speed
Reading Page: Why do bulbs turn on immediately?	Written description	Written and verbal descriptions
Practice:	Descriptive and graph problems; space to record responses	Descriptive and graph problems; text, drawing, and graphing tools to record responses.

but not mandatory for those pursuing an undergraduate degree in elementary education. The study was carried out in two sections of a course taught by the same instructor, Steve (pseudonym), a teacher in residence in the Department of Physics and Astronomy. Steve held a master's degree in physics and had over 30 years of experience teaching science at a public high school located in a suburban town. Ten of those years were spent teaching freshman physics. Before teaching the specialized science content course at the university, Steve was a participant in the 3-year-long professional development program, "A TIME for Physics First," held at a Midwestern university. Steve believed that technology is integral to science teaching, and his classroom teaching reflected his passion through his innovative use of a Smartboard, PhET simulations and other web-based software, such as Go!Motion Vernier software. However, he did not have previous experience teaching using mobile technologies and did not possess a personal iPad. Steve had used the hard-copy version of the curriculum for four semesters before the semester during which the study was conducted; the semester during which the study was conducted was his second semester of teaching using the Exploring Physics app.

The participants included 67 preservice elementary teachers (hereafter referred to as students) enrolled in two sections of the course. The students in the experimental group section (G1, $N = 34$) used the Exploring Physics app on iPads loaned to them for the semester for use in class and at home. This section met three times per week; the Tuesday and Thursday classes were an hour and 50 min long, and the Friday classes were 50 min long. This section consisted of 32 females and two male students; 31 were Caucasian students, two were Hispanic students, and one student was of Asian origin. The comparison group section (G2, $N = 33$) used a hard-copy workbook-based curriculum that was similar in scope and sequence. Students in the comparison group had access to desktop computers in class, with one computer available per group of three or four students. This section met on Mondays, Wednesdays, and Fridays for the same durations as the experimental group. This section consisted of 30 females and three male students; 29 were Caucasian students, three were Hispanic students, and one student was of Asian origin.

Notably, the students chose between the two classes based on their individual schedules and did not know about the research study before choosing their schedules; thus, for the purpose of this study, the students can be considered to have been randomly assigned to the two groups (Cook, Campbell, & Shadish, 2002). The students did not know ahead of time that one of the classes would be using the iPad curriculum (students usually sign up for the course about 3–4 months before school starts). Information about the Exploring Physics app was given to the experimental group on the first day of class, and iPads were loaned to them to use for the entire semester.

5.4 Instrument: Technology Science Teaching Efficacy (TSTE)

The TSTE survey consists of 20 items rated on a 5-point Likert scale ranging from strongly disagree (1) to strongly agree (5). The scores for the survey range from 20 to 100, with higher scores indicating higher levels of technology self-efficacy. The survey is one-dimensional and intended to measure self-efficacy beliefs for technology integration in science teaching. The survey questions were adapted from the Science Teaching Efficacy Belief Instrument (STEBI-B) survey by Bleicher (2004) and Wang et al. (2004). The rationale for selecting items from the two established surveys was that these surveys were valid and reliable and have been by several other studies in the field. Additionally, the two surveys had the potential to be adapted for the preservice elementary teacher population for this study, and they were accessible in terms of administration, analysis, and interpretation. The reliability coefficients reported by Wang et al. (2004) were 0.94 (for the presurvey) and 0.96 (for the postsurvey), indicating that the instrument was highly reliable. The reliability coefficients reported by Bleicher (2004) were 0.87 for the Personal Science Teaching Efficacy Belief subscale and 0.72 for the Science Teaching Outcome Expectancy subscale, indicating that both subscales were within the internal consistency range of accepted values of 0.7–0.9 (Chandrasegaran, Treagust, & Mocerino, 2007).

The questions for the TSTE survey were carefully selected from the Bleicher (2004) and Wang et al. (2004) questionnaires to align with the purposes of this study. One example from the survey is “I feel confident in my ability to continually find better ways to teach science using technologies." First, the survey instrument was administered to 73 elementary education majors (not included as participants in this study). The survey was administered on paper. The Cronbach's α values for this sample were 0.93 (pretest) and 0.94 (posttest). Considering the high reliability values, the TSTE survey (see Appendix A for the complete survey) was used for this study. The standard deviations for the individual survey items are available in Appendix B. The Cronbach's α values showed the internal consistency of the pre- and posttests to be 0.82 and 0.87, respectively, for this sample of participants. These values were well above the accepted range of 0.65 (Chandrasegaran et al., 2007).

5.5 Data collection

During the first phase of data collection and analysis, paper copies of the informed consent forms and TSTE surveys were administered to all students enrolled in the two course sections at the beginning of the semester. The rationale for the study and details about the interview process were shared with students in the classes (the primary researcher read the recruitment script) so they could decide whether to participate in the study. The students' initial TSTE scores were analyzed to create three distinct groups of students within both the experimental and comparison groups for the interviews. Identifying the three distinct groups allowed maximum potential variability among the participants to compare and understand how distinct groups received mobile technology-supported instruction. Informed consent was obtained from all participants who volunteered to be included in the study. Students whose scores were in the top quartile were labeled as the high technology self-efficacy group, students whose scores were in the lowest quartile were labeled as the low technology self-efficacy group, and the remaining students were classified as the medium technology self-efficacy group. Four students from each group (high, medium, and low) agreed to participate in the interviews. Thus, the interview sample consisted of 12 students from the experimental group and another 12 students from the comparison group, for a total of 24 students. This subsample of 24 students included two males and 22 females. We purposefully selected 24 students from the group of 67 volunteers to collect a rich data set to compare and understand the affordances and learning experiences of a mobile technology-supported learning environment that preservice teachers find beneficial for their understandings of science and future science teaching. **Table 3** displays the demographic information of the 24 selected students.

The second phase of data collection involved focus group interviews (three participants from each group) and semistructured interviews (one participant from each group). Therefore, all four participants selected from each distinct group (low, medium, and high) were interviewed either in a focus group or individual interview. Focus group interviews were conducted in addition to individual interviews to gain access to a variety of ideas and expressions as participants exchanged their ideas and commented on each other's points of view in addition to responding to the direct questions posed by the researcher. As Kitzinger (1995) explained, "group processes can help people to explore and clarify their views in ways that would be less easily accessible in a one to one interview" (p. 299). Participants self-selected their preferences to be interviewed in a focus group (in a group of three) or individually. Having more than one interview format, as opposed to only one-on-one interviews, helped us gain access to participants who may have found one-on-one interactions intimidating; thus, creating multiple lines of communication offered participants a safe environment to share their ideas and beliefs (Patton, 2014).

The focus group interviews and individual interviews with the participants in each group (low, medium, and high) were conducted twice, once at the beginning of the semester and again 1 or 2 weeks before the semester concluded. The first interview was designed to understand participants' beliefs and perceptions about using technology, specifically mobile technologies, in teaching and learning science and their prior experiences with mobile technologies. Both the experimental and comparison groups were asked similar questions during the initial interview (see Appendix C). The second interview focused on identifying changes in participants' views and perceptions of teaching and learning science using technologies after their participation in the science content course. While both groups were asked similar questions in their second interviews, the experimental group participants were asked additional questions that targeted their experiences using the Exploring Physics curriculum (see Appendix D). The second

Table 3 Demographic information of the participants ($N = 24$)

Group	*Age (years)*	*No. of science courses in high school*	*Computer-related courses in high school*	*Description of computer-related courses*	*Possess personal iPad (yes/no)*	*Use of iPad (personal, educational, or both)*
Experimental group **(**N **= 12)**						
Low	19–20	4 courses ($N = 2$), 3 courses ($N = 1$), 5 courses ($N = 1$)	2 courses ($N = 2$), None ($N = 2$)	Computer Applications, Excel, Broadcasting, Graphic Design	Yes ($N = 1$), No ($N = 3$)	Personal
Medium	19–20	4 courses ($N = 1$), 3 courses ($N = 1$), 5 courses ($N = 2$)	1 course ($N = 3$), None ($N = 1$)	Typing, Computer Science, Graphic Design	Yes ($N = 1$), No ($N = 3$)	Personal
High	19–20	4 courses ($N = 3$), 5 courses ($N = 1$)	2 courses ($N = 4$)	Computer Applications 1 and 2, Photoshop, Basic Programming, Graphic Design, Typing, Video Editing	Yes ($N = 2$), No ($N = 2$)	Personal ($N = 2$), educational ($N = 1$)
Comparison group **(**N **= 12)**						
Low	19–20	4 courses ($N = 3$), 5 courses ($N = 1$)	1 course ($N = 2$), None ($N = 2$)	Computer Applications, Web Design	Yes ($N = 1$), No ($N = 3$)	Personal
Medium	19–20	4 courses ($N = 2$), 3 courses ($N = 1$), 5 courses ($N = 1$)	2 courses ($N = 3$), None ($N = 1$)	Desktop Publishing, Graphic Design, Photography, Yearbook, Personal Finance	Yes ($N = 3$), No ($N = 1$)	Personal ($N = 3$), educational ($N = 2$)
High	19–20	4 courses ($N = 4$)	1 course ($N = 4$)	Computer Programming 1 and 2, Computer Applications, Information Technology	Yes ($N = 4$)	Personal ($N = 3$), educational ($N = 3$)

interviews with the experimental group also focused on identifying the affordances of the Exploring Physics curriculum that supported their beliefs on learning and teaching science using mobile technologies. The interviews were audio-recorded and transcribed. The interviews served as the primary source of data. Secondary sources of data included weekly classroom observations in both sections (experimental and comparison) and artifacts, including instructors' lesson plans, handouts given in class, and online and hard-copy assignments and student projects. The third phase included the administration of the TSTE survey as a posttest to all participants (N = 67) 1 week before the semester concluded.

5.6 Data analysis

Data analysis proceeded in two distinct phases: (a) a quantitative phase and (b) a qualitative phase. The intent of using quantitative and qualitative techniques for data analysis was to expand on quantitative statistical results with qualitative data. This design is useful, as it allows "bringing together the differing strengths and weaknesses of quantitative methods (trends, generalization) with those of qualitative methods (details, in-depth)" (Plano Clark & Creswell, 2008; p. 62) Below, we describe each of the two phases.

5.6.1 Quantitative data analysis

The TSTE survey data were analyzed using IBM Statistical Package of Social Science (IBM Corp, 2013) software (Version 21.0 for Windows 8). Prepost repeated measures analysis of variance (ANOVA) and posthoc independent sample t tests with Bonferroni adjustment were conducted to determine the statistically significant differences between the means of the experimental and comparison group. The F statistics calculated from Wilks's λ were used to test the significant differences between the mean vectors across time. The group factor (experimental: with iPads; comparison: without iPads) represented the between-subjects factor to test the null hypothesis that there would be no significant differences in the technology self-efficacy for science teaching between the two groups at a given time (pre- and posttest). Paired sample t tests were also used; time was the within-subjects factor to determine the changes in technology self-efficacy for science teaching from pre- to posttest for each group. Cohen's *D* was used to estimate the effect size, as suggested by Morris (2008) for repeated measures designs. The calculation of the effect size (d_{ppc2}) suggested by Morris (2008) was particularly important, considering that the sample sizes of the experimental (N = 34) and comparison (N = 33) groups were different. Furthermore, the estimate of the effect size is well suited for prepost control designs and provides useful estimates of the treatment effects (Morris, 2008). The participants were randomly assigned to the experimental group or comparison group; thus, the calculation of the effect size (d_{ppc2}, where ppc is the prepost control design) controlled for the pre-existing differences between the two groups.

5.6.2 Qualitative data analysis

The qualitative data analysis proceeded in two phases, (a) an inductive phase and (b) a deductive phase. The inductive phase was conducted in three steps using a grounded theory methodology (Strauss & Corbin, 1988). The primary goal of the grounded theory methodology is to generate patterns and themes from the data using inductive reasoning, leading to building a *theory*. While utilizing a grounded theory approach toward analysis, what it means to generate a "theory" is important; Glaser (2017) suggested that "generating a theory involves a process of research" (p. 6). This process provides a strategy for "handling, describing, and explaining" the research data (p. 6). As explained by Strauss and Corbin (1988), a "theory" is conceptualized as a set of themes or categories developed through rigorous and systematic analysis that is "likely to offer insight and enhance understanding" to explain the phenomena being investigated (p. 12). The themes or categories "must be meaningfully relevant to" (p. 3) and be able to explain the phenomenon under investigation (Glaser, 2017). For this study, we employed the grounded theory approach as a methodology for analyzing and interpreting data to understand the complex phenomena of technology self-efficacy beliefs. The approach was well suited for this study because it allowed for analysis through open coding for themes to emerge from the data rather than the use of preexisting categories. This analysis helped identify participants' beliefs, perceptions, and pressing concerns regarding the integration of mobile technologies into science teaching (research questions 1 and 3).

First, the raw data were read and reread for common characteristics, factors, or events as described by the participants, and initial codes were assigned. Second, the initial codes were grouped to generate categories or themes using the axial coding process. All categories and subcategories were revisited to draw meaningful links among them. To establish trustworthiness, two interviews were randomly picked and coded by another researcher who was an expert in qualitative analysis. This strategy allowed cross-checking of the emergent themes from the data. The codes were compared, and any discrepancies between the two independent sets of categories were resolved. The axial coding process continued until saturation was reached, and no new categories or links emerged from the data.

Third, theoretical comparisons were employed in which the data were continuously reviewed to compare incident to incident within and across categories. Theoretical comparison is considered vital for "discovering categories by maximization and minimization of both similarities and differences between the existing categories" (Glaser, 2017, p. 55). This process led to the creation of new categories, reduction of the number of categories, and the creation of subcategories within categories. Once the categories had been established and assigned to individual participants, cross-case analysis was conducted (Yin, 2003). The cross-case analysis allowed us to compare the sets of categories at the individual and group (low, medium, and high) levels to determine the similarities and differences between them. Theoretical comparisons were also made based on prior knowledge and the existing literature. The coding scheme and selected examples are shown in **Table 4.** The analysis of the observation data was similar to the analysis of the interviews. We looked for evidence that supported or refuted the categories and themes that had emerged from the interview data and thus used the observation data to triangulate the findings.

In the deductive phase, the pre-existing categories, as shown in Table 1, were used to identify the affordances of the Exploring Physics curriculum that supported the experimental group participants' beliefs about science teaching and learning using mobile technologies (research question 2). The participants' responses were analyzed under the three dimensions: the device, learner, and social aspects. The categories for each dimension were developed in two ways. First, the

Table 4 Specific examples of the coding schemes

Code	Category	Description	Example
Sample codes for research question 1			
Positive experience with iPads	Positive attitude toward technology	A participant shares his/her willingness to incorporate technology into science teaching	Since we are going to be using them, like whenever we're teachers, and so its nice to get the *experience* with it now rather than in our 1st year of teaching (1M, 2nd interview, experimental group)
Traditional view	Negative attitude toward technology	A participant does not prefer technology and prefers a traditional view of teaching and learning	I *don't like technology-based stuff*, at least with school. I'd rather have a book instead of having homework on iPads. I'd rather do it on a sheet of paper (1L, 2nd interview, experimental group)
Increased confidence	Increased confidence to incorporate technology	A participant reports an increase in his/her confidence to use technology in his/her own future teaching	Everything I've learned in here, whether it is motion, or forces or electricity, I feel a lot more confident with teaching (1H, 2nd interview, experimental group)
Sample codes for research question 2			
Portability and accessibility	All-in-one approach and quick access to information	A participant appreciates the portability of the device (iPads) and quick access to the information while engaged in learning	You have everything in the same space; there is a whiteboard and a calculator on there and the homework. You just had everything on one object, which was nice(2M, 2nd interview, experimental group)
High interactivity and engagement	Variety of tools available within the app	A participant reports the use of app features to be highly interactive and engaging	Being able to whiteboard stuff and draw as well as type and do graphs, it was a lot quicker and easier than doing it on paper (1H, 2nd interview, experimental group)
Sample codes for research question 3			
Frustration			
Unanticipated situations	Technical issues while working on iPads	A participant notes his/her frustration due to technical issues associated with working with the app-based curriculum	There are a lot of little random things, like glitches; when you have to draw something or graph data, you can't see it, so you have to keep going back and forth. It gets kind of frustrating at times (1M, 2nd interview, experimental group)
	Classroom implementation issues	A participant shares his/her fear of not being able to cope with challenges that arise while using technology in teaching science	If you don't know how to necessarily fix them, that could cause problems; like if you are in the classroom and some kid had a problem, unless you know how to fix things, then there is nothing you can do about it (1L, 2nd interview, experimental group)

primary researcher consulted the curriculum developers (two professors in physics) and the course instructor to identify the affordances of the curriculum. Then, the primary researcher grouped each of the affordances under the three dimensions (device, learner, and social). Second, the relevant literature on affordances of mobile technologies was identified; thus, additional codes were added, and existing codes were rearranged under each dimension. The coding scheme was reviewed again by the curriculum developers and the course instructor, and discrepancies were resolved through discussion. Another researcher who was an expert in qualitative analysis reviewed the coding scheme for clarity.

6 Results

6.1 Research question 1: The effect of the Exploring Physics versus hard-copy curriculum on preservice teachers' technology self-efficacy

The study compared changes in preservice teachers' technology self-efficacy beliefs during their participation in the specialized physics content course between the two groups (experimental and comparison). The data from the surveys were tested for the normality of the distribution of scores. The data were acceptable in terms of skewness (<±2.0) and kurtosis (<±2.0). The pre- and posttest means for the two groups along with the paired *t* test results and measures of the effect sizes are presented in **Table 5** and **Figure 4**. For the experimental group, the mean TSTE score significantly increased from

Table 5 Mean scores (standard deviations) and paired samples *t* test results for the TSTE survey

Group	***Pretest mean (SD)***	***Posttest mean (SD)***	*t* ***test***	***Cohen's*** *D*
Comparison (*N* = 33)	80.03 (10.50)	73.69 (11.30)	3.245*	0.31
Experimental (*N*= 34)	76.68 (11.04)	83.21 (9.47)	12.373*	0.64

Abbreviation: TSTE, Technology science teaching efficacy.
*Significant at α « .01.

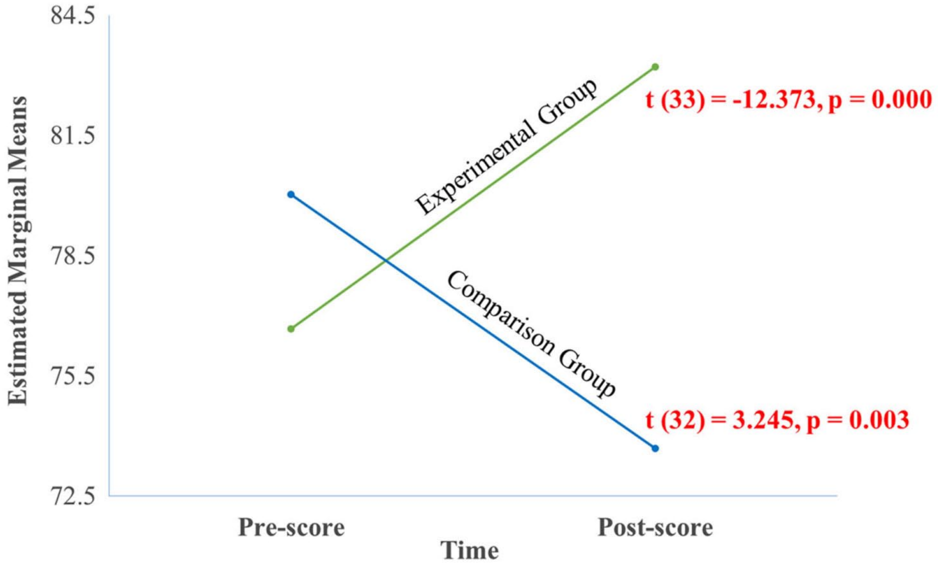


Figure 4 Estimated means at two time-points for the experimental and comparison groups. ($\alpha \ll 0.01$)

pretest (*M*= 76.68, *SD* = 11.04) to posttest (*M*= 83.21, *SD* = 9.47). In contrast, for the comparison group, there was a significant decrease in the mean TSTE score from pretest (*M*= 80.03, *SD* = 10.50) to posttest (*M*= 73.69, *SD* = 11.74). All changes were significant at $\alpha \ll .01$.

For the between-group effects, the Wilks's λ statistics showed significant interactions between time and group [$\Lambda = 0.610$, $F(2, 65) = 41.556$, $p \ll .001$, $\eta^2 = .390$]. Given the significance of the overall ANOVA test (see **Table 6**), posthoc independent sample *t* tests with Bonferroni adjustment were performed (see **Table 7**). There was no significant difference between the two groups at the pretest level ($t = 1.273$, $F = 0.016$, $p > .012$); however, a statistically significant difference was found at the posttest level ($t = 3.655$, $F = 1.323$, $p \ll .012$). Using Cohen's (1988) suggested norms, the moderate effect size of the changes in technology self-efficacy for the experimental group ($d = 0.64$) and small effect size ($d = 0.31$) of the changes in technology self-efficacy for the comparison group was found. There was a large effect size ($d_{ppc2} = 1.189$) for the mean differences between the two groups for the pre- and posttest.

Table 6 Repeated measures analysis of variance ($N = 67$)

Within-subjects effect	***Value***	F	***Sig.***	***Partial***	η^2
Time*Group	Wilks's λ	0.610	41.556*	.000*	0.390

*Significant at α « .05.

Table 7 Posthoc tests with Bonferroni adjustments

Independent samples t ***test***	***df***	t	F	***Sig.***
Pre	65	1.273	0.016	0.207
Post	65	−3.655	1.323	0.001*

*Significant at α « .012.

6.2 Qualitative themes: Experimental group

The emergent themes from the interview responses supported the quantitative results that showed significant increases in the experimental group participants' technology self-efficacy beliefs. Evidence of increased technology self-efficacy for science teaching was demonstrated by the participants' expression of positive views and attitudes regarding technology in science teaching and their enhanced confidence in integrating technology into their future teaching. The excerpts from participants' individual interviews are identified as follows: individuals belonging to the high, medium and low groups are indicated by "H," "M," or "L," respectively, and the data source is indicated by "1" for the first interview and "2" for the second interview. For example, L-2 indicates the second individual interview with a low-efficacy participant in the experimental group. The focus group interviews are identified as "FG," followed by the abbreviations for the efficacy group (low, medium, or high) and the data source (first or second interview). For example, FG-H-2 represents a second focus group interview with a participant belonging to the high-efficacy group.

6.2.1 Positive views and attitudes toward technology integration

In this section, we first discuss participants' views and attitudes toward the integration of technology in science teaching at the beginning of the semester. We then present evidence of shifts in participants' views and attitudes. During the initial interview, we asked participants to describe their views on integrating technologies, specifically mobile technologies, into science teaching. A majority of the participants from all groups viewed technology as a more useful tool when used in upper-elementary grade levels than in kindergarten and lower-elementary grades. For example, one participant mentioned, "Older grades like fourth and fifth grade, they could get it [iPads] more. But kindergartners I feel like would really struggle. I am working with a fifth-grade class now. They just got iPads, and half of the time, they are not even using it because they don't know to use it" (FG-H-1). Another participant asserted, "I don't think kindergartners really need to use technology. I would be frustrated if I had to teach them how to use an iPad while I am teaching them science and the basics of reading and writing" (FG-H-1). In particular, the low group participants' responses indicated negative attitudes about incorporating technology and their hesitance to rely on technology because "technology can have glitches, so one cannot be solely dependent on it" (FG-L-1). Participants in the medium group were concerned about keeping up with the rapid advancements in technology while teaching science. As one participant said, "It [technology] will keep progressing, so that makes it a little harder too. You will have to learn with it as it progresses" (FG-M-1).

During the second interviews, participants were again asked to share their views on integrating technologies, specifically mobile technologies, into their science instruction. Positive shifts in their views and attitudes were evident. Participants from the low group particularly seemed to benefit from the 1:1 exposure to iPad-based learning experiences and had begun to believe that such experiences would benefit their future students as well. Many participants who initially felt anxious about learning science through the use of iPads had become appreciative of learning with iPads, realized the added value of teaching with technology, and become more willing to incorporate technology in their teaching. The excerpts below from the focus group interview illustrate the low group participants' positive attitudes after having first-hand experience with iPads (some text is italicized for emphasis).

> Participant 1: Just getting the initial experience [with iPads] makes me feel better because I know that technology is very

> present in society, so I know it's going to be a part of teaching. Just *having this experience makes me feel better for the future.*
>
> Participant 3: I agree. It's been a good experience to learn more about it [iPads] because if this wouldn't have been the case, I wouldn't have used or bought one before becoming a teacher. *I actually ended up buying one of my own to have more practice on it before I teach*.

Participants from the medium and high groups also appreciated working on iPads for the entire semester, as they could explore other built-in features that they felt would be beneficial for their future teaching. As one participant said, "Just being hands-on with the iPad and getting to know the features—like the video camera on there for my project, the timer, and internet. I have gotten a feel for it, so I will be able to incorporate it in my teaching" (M-2). Another participant from the high group mentioned that having exposure to iPads "every day and for an entire semester helped me to get better over time" (H-2).

6.2.2 Increased confidence to incorporate technology in science teaching

In this section, we first discuss participants' confidence in using technology in science teaching at the beginning of the semester. Then, evidence of participants' enhanced confidence at the end of the semester is presented. At the beginning of the semester, the participants from the low and medium groups seemed less comfortable than those in the high group with the idea of incorporating technology into science instruction. One participant indicated, "We grew up using paper and pencil" (M-1). When asked to elaborate, a majority of these participants indicated a lack of experience using technology in their prior science classes or a lack of knowledge, practice, and training with iPads and other technological tools. For instance, one participant mentioned,

> *I don't know all of the apps and the programs, like how to run them or use them. So it would take a lot of playing around with it by myself before I felt confident in teaching. I don't want to get up in front of the class and be like, "Well, I don't really know how to use this, but we're going to try" (FG-L-1).*

In contrast, the participants from the high group were those who either possessed personal iPads or had been more often exposed to technology in their prior science courses. However, they felt the need for practice or training to gain confidence in teaching science using technology. As one participant from the high group noted, “I know how to use technology because I do all the time, but I would need to dig in more than just opening the app and typing in” (H-1).

At the end of the semester, there were noticeable shifts in participants’ confidence in integrating technology into their future science instruction. For instance, a participant from the medium group initially felt anxious using iPads, explaining, “I’ve never used iPads like this before this class, and definitely never the app, so I didn’t know a whole lot going into it like what it would be like.” However, at the end of the semester, she felt confident about using the iPad in future: “... more of learning and getting comfortable with using the app and doing different things with the iPads that I could use in the classroom in the future” (M-2). Many of the participants felt that they had learned science through the app the same way that they would be expected to teach in the future. They felt better prepared to handle the challenges they might face in their future teaching when using technology because they had worked through those challenges themselves. The excerpt below, from a focus group interview (FG-L-2), illustrates the participants’ gains in confidence:

> *Participant 2: Because, as we’re going through learning the technologies and everything, our students will be having the same struggles. So, the stuff that we’re learning to deal with, whether it is with the technology or the course itself, we’ll be helping our students with the same kind of things.*
>
> *Participant 3: I agree. It helps that that’s how we’ve been learning it [app-based learning]; if I had just been taught without the iPads, then teach someone using it, I would probably have no confidence on how to use the technology.*

The participants in the high group also credited their app-based science learning experiences with contributing to increases in their confidence about teaching science using similar technologies. One participant said, “Everything I’ve learned in here, whether it is motion, or forces or electricity, I feel a lot more confident with teaching. It was interesting getting to know how to use it [the app] and know how convenient it can be in the classroom" (H-2).

6.3 Comparison group

6.3.1 No change in views, attitudes, or confidence regarding technology integration

This section presents the initial and end-of-semester views and attitudes toward the integration of technology into science teaching of the comparison group participants. At the beginning of the semester, the participants' responses were similar to those of the experimental group, and several of the participants expressed their reluctance to incorporate technology into their science teaching. The participants in all groups used words and phrases such as "hassle," "cumbersome," "more of a distraction," "no real learning," "not always reliable," and "hindrance" to describe the use of technology in a science classroom. One participant indicated, "I personally do not like a lot of iPad systems because of the hassle of getting hooked up and set up, and they all rely on the internet usage of the school, and everybody's school network crashes so regularly, and teachers have plans destroyed" (H-1).

During the second interviews, participants were asked about their views on technology integration in science and whether they felt prepared to incorporate technology into their science classrooms. Four clear themes emerged that illustrated participants' negative dispositions and attitudes toward the use of technology in early childhood or elementary science teaching. Importantly, throughout the course, the instructor incorporated various technologies such as a Smartboard, web-based animations and simulations, and software that uses Vernier motion detectors. The software was available on each desktop computer. The first theme to emerge was participants' perceptions of learning science via technology as "unrealistic" and removing learning far from the real world. A majority of the low and medium group participants preferred a more "traditional way" of teaching, as they believed that technology takes away the "hands-on" aspect of learning science. They were convinced that "doing" hands-on experiments is more beneficial for learning science than looking at computer screens at a young age. Furthermore, they were unsure that any technology could facilitate the kind of learning needed for younger students to believe that science is "real." The excerpts from the focus group interview below reflect these attitudes:

> *Participant 2: The hands-on stuff is really cool to get to do, like the balloon in your hair and see that it is static electricity rather than watching a simulation on it.*
>
> *Participant 3: I agree. It's one thing for kids to see it on the computer and be like, "That's impossible," but they do it their self, and they see that it's really real and that it can happen.*

Their statements also illustrated their misconception that hands-on activities are automatically excluded when technology is used. One participant said, "It's just not realistic at all in a lot of areas, so I wonder how productive bringing technology really is in the classroom; are they really learning that much more?" (H-4).

The second theme to emerge was participants' negative views of technology as a hindrance to a child's creative space, especially at a younger age. For example, one participant raised the following question during the focus group interview session: "And where does the creativity come in when you're using technology all the time?" (H-3). Two other participants from the medium group held strong negative opinions on technology and its relevance to society, schools, and students. The expressions below highlight these opinions:

> *Participant 1: It is interesting, though; despite that schools that can't afford it, they're all pushing that we have to use technology because they're getting the funding for it, and if we cannot use our funding, we'd lose it. Then you look at Steve Jobs and Bill Gates who have billions of dollars, and they have extra money to send their kids to prestigious private schools where they don't use technology.*
>
> *Participant 2: Oh yeah. Steve Jobs doesn't let his kids have iPads, Apple computers, iPhones, nothing. Because that's the [time when] creativity and mental processes are still being developed in children. It makes you think from an elementary perspective, we're thrusting technology on these kids and thereby killing their creativity.*

The participants further expressed that socialization is important for children and that working on iPads eliminates the social aspect of learning. One participant expressed that "building social relationships in a classroom and making them [children] work together makes them [social relationships] important for young learners;" therefore, this participant asked, "What socialization is that kid going to get if they have an iPad all day in class and they are isolated on their own?" (L-2). The high group participants expressed mixed views on using technology for science learning. One participant mentioned that younger children might need more practice writing, as "that helps remember and retain information than just having it on iPad" (H-2). However, this participant also believed that students should be exposed to recent developments in technology, as she "would not want kids to be at a disadvantage" (H-2).

The third theme reflected participants' views that being able to use technology is a "privilege" and therefore should not be a priority for teaching science. One participant from the high group mentioned, "Not every child has the same privilege, and I worry about accessibility. Some families don't even have computers, and then some kids haven't even been around that technology before" (H-1). Some participants shared concerns related to "underprivileged families that did not have money for an iPad or a computer" or the prioritization of the basic needs of children below the poverty level. One participant shared, "They [school systems] are making it such a priority before they're even making feeding the kids a priority. There are some kids that can't even afford to get pencils, and they're making these iPads a priority. That is way too expensive" (M-3). Another participant from the medium group responded as follows:

> *Participant 2: Where we are at in society, there is a huge gap. Some people have iPads, and some people can barely afford rulers in their classroom. We are creating a bigger gap in education for the underprivileged schools, and they are getting screwed. Some kids are flying, and others are trying to buy notebooks. We are creating more of a problem with technologies.*

Some participants also expressed concerns regarding the use of technology with children with special needs, who might require a greater amount of time than expected to learn to use the device. One participant said, “If you give a special kid [children with special needs] an iPad and they get lost for 6 hr, for some kids it really works, and other kids there is no way” (M-2). Other participant concerns were related to the ability of technology to fit with the diverse learning styles in a classroom. Two participants believed that the use of technology “depends a lot on the resources of the school, age of the kids, and students’ learning styles” (FG-H-2).

The fourth theme to emerge was the participants’ lack of preparedness to use technology in science teaching. The participants felt that they needed more training and exposure to technology to effectively incorporate technology into their science instruction. One participant mentioned, “I would feel that I would teach them how I’ve been taught, and I wouldn’t want to include technology. I don’t think I am at a point where I can teach it [technology]” (L-2). Many participants felt restricted in their ability to teach science using technology and to be able to handle the situations they anticipated would arise with technology in their classrooms that they may or may not be able to solve. Another participant said, “You have to learn yourself first in order to explain how they should do it. You can’t just be like, “Hey learn this app.” I hardly have that confidence” (M-2). One participant from the low group was concerned about providing solutions to student problems with technology failure and said, “Nothing kills the kid’s interest like watching their teacher for twenty minutes trying to figure out the technology and if you can’t give them an explanation” (L-2).

6.4 Research question 2: Affordances of the Exploring Physics app

The second research question aimed to identify the affordances of the Exploring Physics curriculum that contributed to increases in technology self-efficacy for the experimental group participants. The affordances of the app, as shown in Table 1, varied across groups, and not all categories of affordances appeared in the responses of all three participant groups. The categories were organized into the three aspects: device, learner, and social. In addition, a new category, witnessing successful models of the use of iPads, emerged from the data. Although this category was not exclusive to the app or the use of iPads, witnessing instructor modeling the use of iPads made a positive impact on participants. The categories are described in greater detail below.

6.5 Device aspect of the Exploring Physics app

Two major categories were identified: (a) portability and accessibility and (b) the organization of information within the app. A majority of the participants explicitly stated that having the iPad app enabled them to work on the assignments at any time without carrying an additional load of textbooks. One participant said, "It's nice not having a huge notebook or binder full of stuff, just having it all in one spot that you can go to whenever. It's pretty easy to navigate" (H-2). Participants also appreciated the additional advantage of having quick access to other built-in iPad tools, such as the calculator for problem solving. As one participant mentioned, "You have everything in the same space; there is a whiteboard and a calculator on there and the homework. You just had everything on one object, which was nice" (M-2).

Participants reported that compared to keeping track of sheets of paper, the "all-in-one" aspect helped them become more organized. As one participant mentioned, "It's easier than having to shuffle papers back and forth and sometimes lose them [homework papers] before you turn them in. You can just submit homework online" (L-2). Another participant reported that having the whiteboard feature within the app helped her collect information while in class and later refer to the information while doing homework assignments. She explained, "I'll draw on the whiteboard what he [the instructor] is writing on the board underneath the problems, instead of just having it on a separate notebook that I have to go back and look at" (M-2). Participants frequently related their own learning experiences through iPads to their future science teaching. One participant said, "Definitely there are sources of technology available to teach science to elementary kids, and I will definitely take advantage of that. I know there's a lot of education apps out there, and that could be a good way to get them thinking about science" (H-2).

6.6 Learner aspect of the Exploring Physics app

Three major categories were identified for this aspect: (a) high interactivity, (b) model-building tools, and (c) scaffolds and resources. Participants from all groups mentioned that they found the app highly interactive and engaging. During the classroom observations, the researchers observed students becoming excited about working on iPads, reading instructions on the app to set up their activities, discussing ideas with each other, and simultaneously working on the hands-on activities. Students were often prompted to record their initial ideas on the whiteboard within the app, for instance, to draw an electric circuit to light a bulb with a battery, a bulb, and a wire. The researchers observed students sharing their screens with their table mates and feeling excited about building and testing the circuit they had drawn. Below is an excerpt from the focus group interview (FG-M-2) that reflects these views:

> *Participant 2: I wouldn't have pictured using technology to learn science, but using the iPad and the app is really cool. Doing so many labs, we do a lab every single day rather than just sitting there and watching the screen. We're actually doing hands-on things.*
>
> *Participant 3: It was definitely a different experience because I've never had it [an iPad] in any of my classes. But now, it just seems so normal to have your iPad. I like the step by step as it shows you how we're supposed to be doing the hands-on, like the app is a good guide, but we're still doing it; it's nice to be able to do both.*

Participants saw the value in teaching similarly to how they had learned science through the app. One participant said, "It would be a lot easier to teach with the app or explain it to people" (L-2).

Participants from the medium and high groups described model-building tools that made learning more efficient and made them realize that learning science through mobile technologies could assist their future students as well. One participant said, "Graphing this way [with built-in graphing tools in the app] has given me more confidence" (M-2). Several participants felt that drawing, writing text and using the whiteboard feature on the app increased their efficiency and saved time; as one participant said, “Being able to whiteboard stuff and draw as well as type and do graphs, it was a lot quicker and easier than doing it on paper” (H-1). Conversely, the low group participants frequently expressed their struggles with the model-building tools. One participant mentioned, “I think graphing was really difficult. With the stylus, it was hard to get it right on the spot, and when you had that dot tool, you couldn’t erase it, and it was frustrating” (FG-L-2). Other participants expressed their discomfort with writing equations or doing mathematics within the app; as one participant said, “I don’t know if this is old school, but for the actual math that we have to do, I like to get worksheets that we can write on, because I hated doing the math on the iPad” (FG-L-2).

Participants from all groups, particularly from the low and medium groups, discussed the benefits of the scaffolds and resources available through the app. Their descriptions included quick reference tips and reading pages, built-in videos on problem solving, and access to information via Google or YouTube. Several participants mentioned that the reading pages added clarity, as they could read additional information while doing homework or preparing for a test. One participant said, “When you’re doing homework, you can easily go up and look at the reading pages; it’s just right there for you” (FG-M-2). The low group participants particularly liked the built-in videos and movies on problem solving that they could refer to any time they needed clarity on the concepts. One participant said, “I did like the built-in videos in the app. That is a really positive thing because I am kind of confused about a concept right now, and I am going to go home and watch those videos” (L-2). In addition, participants found the simulations to be helpful for their learning. Furthermore, the simulations provided ideas to incorporate into their own teaching. One participant shared, “Mobile technology puts the power in their [students’] hands so that they could potentially go further in their learning; for instance, we did a toy car on the ramp, and if we want to see how a real car would do on a ramp with friction, we can use simulations. It is fun, and at the same time, it is learning that is self-determined” (H-1).

6.7 Social aspect of the Exploring Physics app

Two major categories were identified: (a) easy communication and (b) the establishment of learning communities. More participants from the low and medium groups stated that they increased their connections with their peers and the course instructor while working on iPads. Several of them referred to the sounding board or chat features in the app, which allowed anyone to post their questions and respond to each other's comments anytime. These features increased their communication with each other outside of class and allowed them to be able to obtain instant responses in real-time when needed. One participant said:

> *Participant 2: As far as the communication on the iPads, there is a sounding board or a chat function, and when we first got it, there were a couple issues with homework worksheets, and I could see on the board people would be like, "Why is this messed up?" So, I knew I was not the only one. (L-2).*

Participants appreciated the fact that they could submit their homework online and receive an instant confirmation message from the instructor. One participant mentioned, "I know for me and for other students, he [the teacher] would respond and say, "Good job, I have gotten everyone's (homework) from this unit," so you knew it went through to him" (M-2). They appreciated receiving immediate feedback on assignments and grades from the instructor online, which they felt "was more convenient rather than waiting for the grades in the next class" (H-2).

The observation data also suggested that in-class communication was significantly better within the experimental group than the comparison group. The hands-on activities and group work designed for both groups were similar; however, the experimental group participants were excited to explore the app features and share as soon as they found something new. Because not all participants were comfortable with "transitioning" to the new environment at the beginning of the semester, they were more willing to collaborate and share their screens and built-in whiteboards to show their findings and to verify their responses. At the same time, student learning communities were formed that regularly met outside of class to collaborate on projects and do homework to be completed through the app. One participant shared, “We had to film ourselves making a compass in water, and we had to use the iPads for that to be able to send it.”

6.8 Witnessing successful models of the use of iPads

Participants from the experimental group benefited from witnessing the many ways in which the course instructor incorporated a variety of technologies into teaching the course, which seemed to positively influence their views on integrating mobile technologies in their teaching. As one participant shared, “He’s [The instructor has] brought in different types of technology, not necessarily computers or iPads, but different types that we use for our labs. Just like watching him, I feel like it’s a good way to learn, like, how to teach” (L-2). The low group participants were greatly impacted by the instructor’s enthusiasm about teaching science using technology and felt that the classroom environment was conducive to learning science that way. Furthermore, it was helpful for the low group participants to see the instructor troubleshoot; witnessing the instructor being successful enhanced their confidence in being able to teach using similar technologies. One participant shared the following example:

> *Participant 2: He will use a real light bulb or whatever he has up there, or he can bring up a real image connecting iPads to the Smartboard, but if the Smartboard is not turning on or the computer shuts down, he can move right over to the whiteboard and do the same thing. He’s really trying to push us as the students to be the ones to give instructions and teach us how to be teachers.*

Another participant said, “Just seeing the instructor teaching and how he uses it [the iPad] and seeing what he does to take it to think about how we would do the same thing has been helpful” (L-1). Several of the participants commented that they felt like “teachers already” because the instructor made explicit connections to future science teaching. The statement below during the focus group interview (FG-L-2) reflects this sentiment:

> *Participant 1: Many times, he took breaks and said, “As a teacher, this is what you want to look for [referring to a*

> *particular technology use].” When somebody asks a question he would be like, “This is a teaching moment; this is a great question on why this person is confused.” So, the instructor really prepared in helping me, because he would constantly connect teaching to how we were learning, which I really liked.*

The instructor stood out as a role model of a science teacher for the comparison group as well; however, the participants in this group referred only to the instructor’s enthusiasm for science with no reference to teaching with technology. In fact, a majority of the low and medium group participants in the comparison group disliked most of the technology used in the course, including the Smartboard and computer simulations. As one participant said, “I feel like he did a really good job *minus the things with the computer*, which I wish he explained it to all of us but instead showed us on the Smartboard. I wish he would have shown us pictures of the buttons [referring to the simulation steps] we were supposed to put” (L-2). This finding is important considering that there was a good amount of technology used in the comparison group but not in the same capacity as in the experimental group, which worked on iPads.

6.9 Research question 3: Persistent concerns regarding the use of iPads

The challenges, as described by the participants, were broadly categorized as (a) technical issues, (b) personal issues, and (c) implementation issues for future classrooms.

6.9.1 Technical issues

One of the major challenges that participants shared was related to glitches within the app. These glitches were largely because certain features within the app were still in the developmental stage. Many of the glitches identified by the participants were addressed by the design support and management team immediately or during the semester. For instance, participants frequently had complaints about saving their drawings or other work completed on the whiteboard featured within the app. As one participant said, “When you do the whiteboard, there’s no way to save it, so that was kind of annoying” (2M-2). The strong weekly communication between the research team, course instructor, and design support team allowed the whiteboard feature to be improved. Other participants shared that the “app shut down suddenly,” that to “flip between pages took much time” and that “the iPad would run down on charge quickly.” These issues made participants hesitant to rely entirely on technology in their future teaching; as one participant noted, “It’s kind of hard just because when you’re doing your homework and the app just shuts off and you’re relying on the app to teach, then you aren’t going to be able to teach your subject” (L-2). While most of the issues were corrected as much as possible right away, the newer version of the app (unavailable at the time of the study) has evolved with newer and more reliable technology.

6.9.2 Personal issues

Participants from the low and medium groups volunteered to discuss their fears on future teaching with technology. When probed, their responses clearly indicated some discomfort with technology because of the initial tensions involved in working in a newer environment of learning science using iPads. For instance, one participant shared that she remembers material better when handwriting than when typing and explained, “When I’m typing, I go through it, and it goes right over my head” (L-2). She further added that “kids might not take it [working on iPads] seriously” (L-2). These experiences created a dilemma in teaching science with technology, and the participants’ statements reflected their comfort with the traditional methods of learning and teaching science. Some participants felt additional pressure learning the material while also learning how to use the app. As one participant said, “Besides just learning the material, you have the pressure of learning the technology” (M-2).

Another issue raised by participants from the low group was the differences between the modes of learning in class (on iPads) and the mechanisms through which the assessments were conducted (with paper and pencil) in the course. The low group participants shared that while most of the science learning, including lessons, classwork, and homework, occurred through the iPad and the app, their tests involved worksheets using paper and pencil. The participants’ comments indicated that they were uncomfortable with the differences between the learning and assessment strategies and, at times, blamed these differences for their poor performances on quizzes or tests. As one participant said, “In some ways, when you learn it [material] in a certain mode, you can try to transfer it [to paper-and-pencil tests], but there will be some loss of information between the two” (L-2). The conversation below from the focus group (FG-L-2) also reflects this difficulty:

> *Participant 1: If we’re going to do all of the homework and all of the work on the iPads, the test should be on the iPads, because the brain associates with where you learned; you will be most comfortable taking a test where you learned your information. So that could potentially lower your score a little bit because that is a conflicting mode with how you learned it and how you are trying to regurgitate what you learned.*
>
> *Participant 2: If you were to do all your graphing on an iPad, then you’re teaching them this is somewhat what a graph would look like...and then you come to a test, and you’ve only graphed on the iPad.*

This category did not appear in the responses of the high or medium group participants.

6.9.3 Implementation issues for future teaching

Participants from all groups were concerned about unanticipated situations related to technological failure that could arise in their future classrooms. One participant explicitly stated that “teachers cannot be technicians” (H-2). Similar statements made by participants reflected that they felt unprepared to handle questions that their future students might ask about technology. One participant from the medium group stated, “If you don’t know how to necessarily fix them, that could cause problems; like if you are in the classroom and some kid had a problem, unless you know how to fix things, then there is nothing you can really do about it” (M-2). Others were concerned about the school logistics related to the implementation of technology in classrooms, such as budgetary issues, available training, technical support, and access to information via the internet. Some were unsure about other apps available to use in their science instruction or their ability to select an appropriate app from the available pool to cater to their students’ needs. As one participant said, “It would be really helpful to know how to find different apps because when I look up science apps, some of them are really bad, and some of them are okay. It's hard to know the difference" (L-2).

7 Discussion and Implications

7.1 Development of technology self-efficacy beliefs

This study provides evidence for the effectiveness of an innovative iPad-based physics curriculum, Exploring Physics, in supporting preservice teachers' technology self-efficacy beliefs in a specialized physics content course. While the current research adds to the existing literature based on preservice teachers' technology self-efficacy beliefs, the study is unique in many ways in addressing some of the existing empirical gaps in the literature regarding mobile technologies and preservice teacher education. First, the majority of prior studies on technology self-efficacy have been framed within the context of science methods or education technology courses. Given that science content courses are an important part of preservice teacher programs, our study documents changes in the technology self-efficacy of preservice teachers enrolled in a science content course. Second, unlike prior studies, our study documents results from *long-term* exposure to learning via mobile technology (iPads) on preservice teachers' technology self-efficacy. Third, the study provides evidence on *how* and *why* mobile technology-based approaches to science learning positively enhanced preservice teachers' technology self-efficacy beliefs. Fourth, our study identifies challenges that continued to affect preservice teachers' perceptions of integrating mobile technologies in science teaching.

In this study, we compare changes in preservice teachers' technology self-efficacy beliefs between two groups, one engaged in science learning through the Exploring Physics curriculum on iPads (experimental group) and another that used a hard-copy version of a similar curriculum (comparison group). The findings of this study reveal significant positive gains in participants' technology self-efficacy for the experimental group. This finding is in accord with the findings of other studies that explored technology self-efficacy beliefs within the context of science methods or education technology courses (Anderson et al., 2011; Koh & Frick, 2009; Rehmat & Bailey, 2014; Wang et al., 2004). A moderate effect (d = 0.64) was found for the experimental group participants' technology self-efficacy, which suggests that participants' first-hand engagement with iPads may have contributed to positive perceptions of teaching science using technology. Meanwhile, a small effect (d = 0.31) was found for the comparison group participants' technology self-efficacy; however, there was a large effect (d_{ppc2} = 1.189) for the mean differences of the two groups for the pre- and posttest. This finding suggests that the estimate of the treatment effect, that is, the use of the Exploring Physics curriculum, is large.

Interestingly, there was a significant decrease in the comparison group participants' technology self-efficacy. One logical explanation for the decrease could be that since both sections ran parallel during the semester, though on alternative days, several students were aware that the experimental group was learning science with the use of iPads. Some of the discussions outside the class between students from the two groups may have contributed to the lower technology self-efficacy of the comparison group participants. One of the major concerns raised by participants in both groups was the disconnect between ways they had learned science as K-12 students, using paper-and-pencil worksheets, and the way they are expected to teach considering the growing demand to teach science with technology. To meet these demands, preservice teachers must learn science content in similar ways to the ways in which they are expected to teach it in the future (Anderson, Smith, & Peasley, 2000). Preservice teachers can feel discomfort with technology, which is unsurprising when they have not experienced using mobile technologies as K-12 students (Brown et al., 2016). Many participants in the comparison group had a strong affinity toward hands-on learning, and for them, it was difficult to internalize the fact that technology is not a replacement to hands-on learning but a tool for young children to experience new information. Other studies of games/apps have also documented that preservice teachers struggle to find a link between the use of technology and its effects on student learning (Mourlam & Montgomery, 2015; Plass, Homer, Kinzer, Frye, & Perlin, 2011).

Prior research has suggested that time spent one-on-one with technology is one of the key factors influencing preservice teachers' beliefs about technology (Chen, 2010; Franklin, 2007). Notably, preservice teachers in the experimental group particularly benefited from the long-term exposure to mobile technology through the app, which provided them with successful models of the adequate and appropriate use of mobile technologies in science teaching. This finding is consistent with the existing notion in the literature that explicit instruction that exposes preservice teachers to pedagogies of successful technology use can yield long-term benefits in science teaching and learning (Looi et al., 2010; Rehmat & Bailey, 2014). In contrast, the comparison group spent much less time exploring the educational use of technology. Moreover, possible affordances and constraints of any technological tool for science teaching can be realized only after using the tool with a science lesson, which the comparison group did not do (Freidhoff, 2008). It seemed difficult for participants in the comparison group to recognize the value and benefits of technology in science education without any first-hand experience of learning science using technology. Rather, their underlying beliefs about the use of technology, which were negative at the beginning of the semester, were solidified at the end of the semester because they felt comfortable with learning physics without the use of technology and therefore did not perceive that they were at any loss without the use of iPads.

The patterns observed in both groups' interview responses also supported the trends from the posttest results. Participants, particularly those from the low and medium experimental groups, had more positive views and attitudes about technology integration toward the end of the semester. This finding is particularly important to help preservice teachers to develop an appreciation for using technology in science, especially during science content courses (Rehmat & Bailey, 2014). Prior empirical work has documented that factors such as "training, value, and efficacy" strongly influence preservice teachers' use of technology (Chen, 2010; Ertmer et al., 2006). Evidently, experiences with technology during teacher education programs, referred to as "training," help preservice teachers enhance their technology self-efficacy (Chen, 2010, Ertmer, 2005). Thus, teachers' positive technology self-efficacy beliefs based on their experiences with

Exploring Physics may be more likely to be carried forward in their subsequent science methods courses, field experiences, and eventually classroom teaching.

The study has major implications for preservice teacher preparation and future research. First, it provides evidence that explicit and long-term use of mobile technologies and app-based curricula has the potential to enhance technology self-efficacy; more science content and methods courses should be designed to facilitate such a mobile technology-supported learning environment. This type of environment is particularly important for preservice teachers who have had little or no experience with learning science through technology in their prior science courses, as in the case of this study. Evidently, such an environment may have positive lasting effects on preservice teachers' technology self-efficacy (Wang et al., 2004). Second, continuous mentoring and support is needed for preservice teachers to overcome their initial fears and help them adjust to working in a new environment of learning science using technology. In this study, the frustrations and initial anxiety of working with iPads and the app at the beginning of the semester was evident. Nearly half of the preservice teachers had no prior experience using iPads for science learning, even though every participant reported being familiar with using iPhones and iPads for their personal use. Furthermore, participants clearly felt frustrated, as they felt pressure to learn both the new technology and the physics content. Science educators need to be aware of the struggles preservice teachers could have while learning science in ways they may not have observed, witnessed, or experienced previously. In addition, explicit discussions on connecting the affordances of apps to their success in science learning will help preservice teachers to become committed to teaching science using mobile technologies.

Instructors should be aware that managing and facilitating such an environment can be challenging and may require rigorous training to implement mobile technology-based curricula, such as Exploring Physics. Every technology has its tradeoffs (Wilson et al., 2013) instructors should be aware of such tradeoffs and hold discussions with preservice teachers to prepare them for unanticipated challenges in future teaching. It would help preservice teachers to use similar technologies that they have experienced in their science content courses in their science methods courses and field placements. In addition, science content courses that integrate technologies could provide opportunities for preservice teachers to develop small-group projects and give presentations to the whole class using technologies they used in the course or to practice peer-teaching a concept using technology. Such experiences may enhance preservice teachers' confidence in using technology before they enter their science methods courses. Furthermore, creating instructional opportunities for preservice teachers to plan and implement technology-rich lessons during their field placements would help them witness the use of such devices to promote student learning (Hoban & Nielsen, 2014).

Another consideration is the fact that only a few preservice teacher education programs employ mobile technologies within their science content or methods courses, while many programs feature stand-alone technology courses. Even if mobile technologies are introduced in science content or methods courses, they are often used for a small stand-alone project or an activity, which suggests that they are not integrated as a routine practice (Looi et al., 2014). Thus, in many cases, preservice teachers may still maintain their fears of teaching science with technology, which may impact their use of technology in their student teaching or later teaching careers (Looi et al., 2014). In this study, mobile technology was an integral part of science learning for the experimental group, but it is still necessary to reinforce successful models of technology use in preservice teachers' subsequent science methods courses and student teaching seminars to maximize benefits for technology self-efficacy. In addition, longitudinal studies are needed to continue to explore how technology self-efficacy beliefs are developed throughout preservice coursework, student teaching placements, and the early years of classroom teaching. Studies should continue to examine the intrinsic and extrinsic factors that support technology self-efficacy beliefs beyond college coursework and the extent to which preservice teachers' classroom practices reflect technology integration in their science teaching.

7.2 Affordances of mobile Technology-based science curricula

Past studies have documented the affordances of mobile learning for developing preservice teachers' views and attitudes toward technology (Looi et al., 2010; Rehmat & Bailey, 2014) and technology self-efficacy (Anderson et al., 2011; Banas & York, 2014). The unique affordances of the Exploring Physics app promoted a student-centered learning environment by allowing students to experience science learning through technology-rich lessons. The design features of the Exploring Physics app were categorized under three aspects of the FRAME model: the device, learner, and social aspects. Each of these aspects offered opportunities for more self-directed learning tailored to participants' needs, which appeared to increase participants' technology self-efficacy. Notably, the design features and affordances of app-based learning particularly benefited preservice teachers who initially held negative attitudes toward technology and had low initial technology self-efficacy beliefs.

One of the popular emergent themes under the device aspect was the accessibility and portability of learning via iPads, which allowed preservice teachers to access material offline and have multiple opportunities to explore other resources via the internet. Previous empirical studies have also noted that preservice teachers benefit from learning anytime/anywhere with the use of mobile devices (O'Bannon & Thomas, 2015). The use of mobile devices has been claimed to increase productivity because of the 1:1 interaction with the device (Dunleavy, Dexter, & Heinecke, 2007). In this study, preservice teachers in the experimental group had 1:1 exposure to learning via iPads, which allowed for personalized learning (learner aspect). Specifically, participants from all groups (low, medium, and high) benefited from the model-building tools, reading pages, and built-in videos to which they always had access. In addition, the app included animations, simulations, on-demand definitions and hints (scaffolds), movies, a chat function, and digital assignment submission to the teacher. The experimental group participants found such features to be highly interactive and beneficial to their learning, and they were inclined to use them in their future classrooms. None of these functionalities were available in the hard-copy workbook.

The app offered opportunities for both personalized learning and social interaction among preservice teachers (social aspect), which seemed to impact technology self-efficacy. For instance, the sounding board and chat features allowed students to connect to others as a *whole class team*, post relevant questions, and respond to each other.

This feature particularly helped low group participants discuss their struggles. Furthermore, working in small groups in class as well as collaborating on projects outside class time promoted social interaction among the experimental group participants because many participants, especially from the low group, felt connected via the app. Preservice teachers need opportunities to discuss their concerns in supportive contexts, which affects their perceptions about technology (Anderson et al., 2011).

The FRAME model (Koole, 2009) is both *broad* and *specific* and is a helpful guide for the development of learning materials for mobile education. In addition, it offers flexibility for researchers and curriculum developers to see what fits within the goals and needs of their students to promote mobile learning with a particular context. Additionally, the three aspects (device, learner, and social) can serve as a guide for classroom teachers and curriculum developers to create new science activities based on mobile learning. Notably, the FRAME model allowed us to better comprehend the complex nature of mobile learning (Koole, 2009). More studies are needed to explore the interactions between the three aspects (device, learner, and social) as well as the intersections between pairs of aspects.

It is important to note that developing mobile technology-driven courses could be a time- and labor-intensive process. Notably, the technical issues encountered by preservice teachers while engaged with the app were resolved quickly because of the connectivity between the technical support team and the implementation team. This level of connectivity within school technical support teams and classroom teachers may not always be possible in real time. Thus, explicit discussions on careful planning and implementation, preparation to handle unanticipated situations and possible solutions are warranted. Certainly, we do not advocate that science instruction depend solely on the use of mobile technologies, nor do we recommend replacing traditional-style learning completely. However, considering the popularity of mobile devices among young children (Goggin, 2012; Zhang, 2015), mobile-based curricula, such as Exploring Physics, can serve as effective tools for elementary science instruction. Research on the integration of mobile technologies for preservice coursework is an exciting and new area, and studies should continue to explore how to leverage mobile technology-supported learning environments to maximize their benefits for science teaching and learning.

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References

Allsopp, D. H., McHatton, P. A., & Cranston-Gingras, A. (2009). Examining perceptions of systematic integration of instructional technology in a teacher education program. *Teacher Education and Special Education*, *32*(4), 337–350.

Anderson, S. E., & Maninger, R. M. (2007). Preservice teachers' abilities, beliefs, and intentions regarding technology integration. *Journal of Educational Computing Research*, *37*(2), 151–172.

Anderson, S. E., Groulx, J. G., & Maninger, R. M. (2011). Relationships among preservice teachers' technology-related abilities, beliefs, and intentions to use technology in their future classrooms. *Journal of Educational Computing Research*, *45*(3), 321–338.

Anderson, L. M., Smith, D. C., & Peasley, K. (2000). Integrating learner and learning concerns: Prospective elementary science teachers' path and progress. *Teaching and Teacher Education*, *16*(5), 547–574.

Appleton, K., & Kindt, I. (2002). Beginning elementary teachers' development as teachers of science. *Journal of Science Teacher Education*, *13*(1), 43–61.

Atwater, M. M. (1996). Social constructivism: Infusion into the multicultural science education research agenda. *Journal of Research in Science Teaching*, *33*(8), 821–837.

Banas, J. R., & York, C. S. (2014). Authentic learning exercises as a means to influence preservice teachers' technology integration self-efficacy and intentions to integrate technology. *Australasian Journal of Educational Technology*, *30*(6), 728–746.

Bandura, A. (1977). Self-efficacy. Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215.

Bebell, D., & O'Dwyer, L. M. (2010). Educational outcomes and research from 1:1 computing settings. *Journal of Technology, Learning, and Assessment*, *9*(1), 5–15.

Bell, R. L., Maeng, J. L., & Binns, I. C. (2013). Learning in context: Technology integration in a teacher preparation program informed by situated learning theory. *Journal of Research in Science Teaching*, *50*(3), 348–37.

Bleicher, R. E. (2004). Revisiting the STEBI-B: Measuring self-efficacy in preservice elementary teachers. *School Science and Mathematics*, *104*(8), 383–391.

Bleicher, R. E., & Lindgren, J. (2005). Success in science learning and preservice science teaching self-efficacy. *Journal of Science Teacher Education*, *16*(3), 205–225.

Brand, J., Forder, J., Hives, L., Hrivnak, G., Kenworthy, A., Keyzer, P., … Watt, B. (2010). *mLearning@Bond: Report of the Academic Discussion Group on the Prospect of Mobile Learning at Bond University*. Gold Coast: Bond University.

Brand, J., & Kinash, S (2010). *Pad-agogy: A quasi-experimental and ethnographic pilot test of the iPad in a blended mobile learning environment*. 27th Annual Conference of the Australian Society for Computers in Learning in Tertiary Education (ASCILITE). Sydney, Australia.

Brand, J., Kinash, S., Mathew, T., & Kordyban, R. (2011). iWant does not equal iWill: Correlates of mobile learning with iPads, e-textbooks, BlackBoard Mobile Learn and a blended learning experience, *In Proceedings ASCILITE 2011: 28th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education: Changing Demands, Changing Directions* (pp. 168–178). University of Tasmania.

Brown, C. P., Englehardt, J., & Mathers, H. (2016). Examining preservice teachers' conceptual and practical understandings of adopting iPads into their teaching of young children. *Teaching and Teacher Education*, *60*, 179–190.

Chandrasegaran, A. L., Treagust, D. F., & Mocerino, M. (2007). The development of a two-tier multiple-choice diagnostic instrument for evaluating secondary school students' ability to describe and explain chemical reactions using multiple levels of representation. *Chemistry Education Research and Practice*, *8*(3), 293–307.

Chen, R. (2010). Investigating models of preservice teachers' use of technology to support student-centered learning. *Computers and Education*, *55*(1), 32–42.

Chu, H. C., Hwang, G. J., Tsai, C. C., & Tseng, J. C. (2010). A two-tier test approach to developing location-aware mobile learning systems for natural science courses. *Computers and Education*, *55*(4), 1618–1627.

Churchill, D., Fox, B., & King, M. (2012). Study of affordances of iPads and teachers' private theories. *International Journal of Information and Education Technology*, *2*(3), 251–254.

Common Sense Media (2017). *The common sense consensus: Media use by kids age zero to eight*. Retrieved from https://www.commonsensemedia.org/sites/default/files/uploads/research/csm_zerotoeight_fullreport_release_2.pdf

Cook, T. D., Campbell, D. T., & Shadish, W. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Boston: Houghton Mifflin.

Couse, L. J., & Chen, D. W. (2010). A tablet computer for young children? Exploring its viability for early childhood education. *Journal of Research on Technology in Education*, *43*(1), 75–96.

Crook, S. J., Sharma, M. D., Wilson, R., & Muller, D. A. (2013). Seeing eye-to-eye on ICT: Science student and teacher perceptions of laptop use across 14 Australian schools. *Australasian Journal of Educational Technology*, *29*(1), 82–95.

Crowther, D. T., & Bonnstetter, R. J. (1997). *Science experiences and attitudes of elementary education majors as they experience Biology 295: A multiple case study and substantive theory*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching. Oak Brook, IL.

de Winter, J., Winterbottom, M., & Wilson, E. (2010). Developing a user guide to integrating new technologies in science teaching and learning: Teachers' and pupils' perceptions of their affordances. *Technology, Pedagogy and Education*, *19*(2), 261–267.

DeCoito, I., & Richardson, T. (2018). *Teachers and technology: Present practice and future directions*. Contemporary Issues in Technology and Teacher Education, 18(2). Retrieved from http://www.citejournal.org/volume-18/issue-2-18/science/teachers-and-technology-present-practice-and-future-directions

Denscombe, M. (2008). Communities of practice. *Journal of Mixed Methods Research*, *2*, 270–283.

Dunleavy, M., Dexter, S., & Heinecke, W. F. (2007). What added value does a 1:1 student to laptop ratio bring to technology-supported teaching and learning? *Journal of Computer Assisted Learning*, *23*(5), 440–452.

El-Hussein, M. O. M., & Cronje, J. C. (2010). Defining mobile learning in the higher education landscape. *Educational Technology & Society*, *13*(3), 12–21.

Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & R. -L. Punamaki-Gitai (Eds.), *Perspectives on activity theory: Learning in doing* (pp. 19–38). Cambridge: Cambridge University Press.

Enochs, L. G., & Riggs, I. M. (1990). Further development of an elementary science teaching belief instrument: A preservice elementary scale. *School Science and Mathematics*, *90*(8), 694–706.

Enriquez, A. G. (2010). Enhancing student performance using tablet computers. *College Teaching*, *58*(3), 77–84. https://doi.org/10.1080/87567550903263859

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational Technology Research and Development*, *53*(4), 25–39.

Ertmer, P. A., Conklin, D., Lewandowski, J., Osika, E., Selo, M., & Wignall, E. (2003). Increasing preservice teachers' capacity for technology integration through the use of electronic models. *Teacher Education Quarterly*, *30*(1), 95–112.

Ertmer, P. A., Ottenbreit-Leftwich, A., & York, C. S. (2006). Exemplary technology-using teachers: Perceptions of factors influencing success. *Journal of Computing in Teacher Education*, *23*(2), 55–61.

Franklin, C. (2007). Factors that influence elementary teachers use of computers. *Journal of Technology and Teacher Education*, *15*(2), 267–293.

Franklin, T. (2011). Mobile learning: At the tipping point. *The Turkish Online Journal of Educational Technology*, *10*(4), 261–275.

Freidhoff, J. R. (2008). Reflecting on the affordances and constraints of technologies and their impact on pedagogical goals. *Journal of Computing in Teacher Education*, *24*(4), 117–122.

Glaser, B. (2017). *Discovery of grounded theory: Strategies for qualitative research*. New York: Routledge.

Goggin, G. (2012). *Cell phone culture: Mobile technology in everyday life*. New York: Routledge.

Gunning, A. M., & Mensah, F. M. (2011). Preservice elementary teachers' development of self-efficacy and confidence to teach science: A case study. *Journal of Science Teacher Education*, *22*(2), 171–185.

Hernández-Ramos, P. (2005). If not here, where? Understanding teachers' use of technology in Silicon Valley schools. *Journal of Research on Technology in education*, *38*(1), 39–64.

Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development*, *55*(3), 223–252.

Hoban, G., & Nielsen, W. (2014). Creating a narrated stop-motion animation to explain science: The affordances of "Slowmation" for generating discussion. *Teaching and Teacher Education*, *42*, 68–78.

Holden, H., & Rada, R. (2011). Understanding the influence of perceived usability and technology self-efficacy on teachers' technology acceptance. *Journal of Research on Technology in Education*, *43*(4), 343–367.

Hsu, Y. C., & Ching, Y. H. (2015). A review of models and frameworks for designing mobile learning experiences and environments. *Canadian Journal of Learning and Technology*, *41*(3), 1–22.

IBM Corp. Released (2013). *IBM SPSS statistics for windows*. Armonk, NY: IBM Corp. Version 22.0. Jennings, G., Anderson, T., Dorset, M., & Mitchell, J. (2010). *Report on the step forward iPad pilot project.* Melbourne: Trinity College, University of Melbourne. Retrieved from http://goo.gl/UuwXG

Koh, J. H., & Frick, T. W. (2009). Instructor and student classroom interactions during technology skills instruction for facilitating preservice teachers' computer self-efficacy. *Journal of Educational Computing Research*, *40*(2), 211–228.

Keskin, N. O., & Metcalf, D. (2011). The current perspectives, theories and practices of mobile learning. *The Turkish Online Journal of Educational Technology*, *10*(2).

Kinash, S. (2011). *It's mobile, but is it learning? Learning and teaching papers*. Retrieved from http://epublications.bond.edu.au/tls/29

Kitzinger, J. (1995). Qualitative research Introducing focus groups. *British Medical Journal*, *311*(7000), 299–302.

Koole, M. L. (2009). A model for framing mobile learning. *Mobile Learning: Transforming the delivery of education and training*, *1*(2), 25–47.

Liu, M., Navarrete, C. C., Scordino, R., Kang, J., Ko, Y., & Lim, M. (2016). Examining teachers' use of iPads: Comfort level. *Perception, and Use. Journal of Research on Technology in Education*, 1–22.

Liu, M., Navarrete, C. C., & Wivagg, J. (2014). Potentials of mobile technology for K-12 education: An investigation of iPod touch use for English language learners in the United States. *Journal of Educational Technology and Society*, *17*(2), 115–126.

Looi, C. K., Zhang, B., Chen, W., Seow, P., Chia, G., Norris, C., ... Soloway, E. (2010). 1:1 mobile inquiry learning experience for primary science students: A study of learning effectiveness. *Journal of Computer Assisted Learning*, *27*(3), 269–287.

Looi, C. K., Sun, D., Wu, L., Seow, P., Chia, G., Wong, L. H., ... Norris, C. (2014). Implementing mobile learning curricula in a grade level: Empirical study of learning effectiveness at scale. *Computers & Education*, *77*, 101–115.

Lumpe, A. T., & Chambers, E. (2001). Assessing teachers' context beliefs about technology use. *Journal of Research on Technology in Education*, *34*(1), 93–107.

Menon, D., Chandrasekhar, M., Kosztin, D., & Steinhoff, D. (2017). Preservice elementary teachers' science self-efficacy beliefs and science content knowledge. *Contemporary Issues in Technology and Teacher Education*, *17*(3).

Molner, M. (2015, February). Half of K-12 students to have access to 1 to 1 computing by 2015-16. *Education Week*. Retrieved from http://blogs.edweek.org/edweek/marketplacek12/2015/02/half_of_k-12_students_to_have_access_to_1-to-1_computing_by_2015-16_1.html

Moore, M. (1989). Editorial: Three types of interaction. *The American Journal of Distance Education*, *3*(2), 1–6.

Morris, S. B. (2008). Estimating effect sizes from pretest-posttest-control group designs. *Organizational Research Methods*, *11*(2), 364–386.

Morse, J. M., & Niehaus, L. (2009). *Mixed method design: Principles and procedures*. Walnut Creek, CA: Left Coast Press.

Mourlam, D., & Montgomery, S. (2015). iPads and teacher education: Exploring a 1;1 initiative in a professional development school partnership. *Journal of Digital Learning in Teacher Education*, *31*, 107–116.

Niederhauser, D. S., & Stoddart, T. (2001). Teachers' instructional perspectives and use of educational software. *Teaching and Teacher Education*, *17*(1), 15–31.

O'Bannon, B. W., & Thomas, K. M. (2015). Mobile phones in the classroom: Preservice teachers answer the call. *Computers & Education*, *85*, 110–122.

Oliver, T. A., & Shapiro, F. (1993). Self-efficacy and computers. *Journal of Computer-Based Instruction*, *20*, 81–85.

Oxford, R. L. (1997). Cooperative learning, collaborative learning, and interaction: Three communicative strands in the language classroom. *The Modern Language Journal*, *81*(4), 443–456.

Park, Y. (2011). A pedagogical framework for mobile learning: Categorizing educational applications of mobile technologies into four types. *The International Review of Research in Open and Distributed Learning*, *12*(2), 78–102.

Patton, M. Q. (2014). *Qualitative evaluation and research methods*. Thousand Oaks, CA: SAGE Publications, Inc.

Piper, D. (2003). The relationship between leadership, self-efficacy, computer experience, attitudes, and teachers' implementation of computers in the classroom. In C. Crawford, D. Willis, R. Carlsen, I. Gibson, K. McFerrin, J. Price, & R. Weber (Eds.), *Proceedings of the Society for Information Technology in Teacher Education* (pp. 1057–1060). Chesapeake, VA: AACE.

Pegrum, M., Howitt, C., & Striepe, M. (2013). Learning to take the tablet: How preservice teachers use iPads to facilitate their learning. *Australasian Journal of Educational Technology*, *29*(4), 464–479.

Plano Clark, V. L., & Creswell, J. W. (2008). *The mixed methods reader*. Thousand Oaks, CA: Sage.

Plass, J. L., Homer, B. D., Kinzer, C. K., Frye, J., & Perlin, K. (2011). *Learning mechanics and assessment mechanics for games for learning*. New York. NY: Games for Learning Institute.

Poll, H. (2015). *Pearson student mobile device survey 2015. National report: students in grades 4-12*. Retrieved from https://www.pearsoned.com/wp-content/uploads/2015-Pearson-Student-Mobile-Device-Survey-Grades-4-12.pdf

Pope, M., Hare, D., & Howardy, E. (2002). Technology integration: Closing the gap between what preservice teachers are taught to do and what they can do. *Journal of Technology and Teacher Education*, *10*(2), 191–204.

Quinn, C. (2000) mLearning: Mobile, wireless and in-your-pocket learning. Line Zine Magazine. Retrieved from http://www.linezine.com/2.1/features/cqmmwiyp.htm

Ramey-Gassert, L., & Shroyer, M. G. (1992). Enhancing science teaching self-efficacy in preservice elementary teachers. *Journal of Elementary Science Education*, *4*(1), 26–34.

Rehmat, A. P., & Bailey, J. M. (2014). Technology integration in a science classroom: Preservice teachers' perceptions. *Journal of Science Education and Technology*, *23*(6), 744–755.

Rice, D. C., & Roychoudhury, A. (2003). Preparing more confident preservice elementary science teachers: One elementary science methods teacher's self-study. *Journal of Science Teacher Education*, *14*(2), 97–126.

Rossing, J. P., Miller, W. M., Cecil, A. K., & Stamper, S. E. (2012). iLearning: The future of higher education? Student Perceptions on Learning with Mobile Tablets. *Journal of the Scholarship of Teaching and Learning*, *12*(2), 1–26.

Seppälä, P., & Alamäki, H. (2003). Mobile learning in teacher training. *Journal of Computer Assisted Learning*, *19*(3), 330–335.

Shepardson, D. P. (1999). Learning science in a first grade science activity: A Vygotskian perspective. *Science Education*, *83*(5), 621–638.

Shuler, P., Hutchins, G., & LaShell, B. (2010). Student perceptions of tablet computers in a cooperative learning environment. *NACTA Journal*, *54*(2), 11–17.

Strauss, A., & Corbin, J. (1988). *Basics of qualitative research: Techniques and procedures of developing grounded theory*. Thousand Oaks, CA: Sage.

Tondeur, J., Valcke, M., & van Braak, J. (2008). A multidimensional approach to determinants of computer use in primary education: Teacher and school characteristics. *Journal of Computer Assisted Learning*, *24*, 494–506.

Traxler, J. (2009). Current state of mobile learning. In M. Ally (Ed.), *Mobile learning: Transforming the delivery of education and training* (pp. 9–24). Athabasca: University Press.

US Department of Education (2010). Transforming American education: Learning powered by technology. Washington, DC: Office of Educational Technology. Retrieved from https://www.ed.gov/sites/default/files/netp2010.pdf

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Venkatesh, V., Morris, M., Davis, G., & Davis, F. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, *27*, 425–478.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge: Harvard University Press.

Wang, L., Ertmer, P. A., & Newby, T. J. (2004). Increasing preservice teachers' self-efficacy beliefs for technology integration. *Journal of Research on Technology in Education*, *36*(3), 231–250.

Wilson, R., Goodman, J., Bradbury, L., & Gross, L. (2013). Exploring the use of iPads to investigate forces and motion in an elementary science methods course. *Contemporary Issues in Technology and Teacher Education*, *13*(2), 105–126.

Wu, W. H., Wu, Y. C. J., Chen, C. Y., Kao, H. Y., Lin, C. H., & Huang, S. H. (2012). Review of trends from mobile learning studies: A meta-analysis. *Computers and Education*, *59*(2), 817–827.

Yin, R. K. (2003). *Case study research: Design and methods* (3rd ed.). Thousand Oaks, CA: Sage.

Zhang, Y. A. (Ed.). (2015). *Handbook of mobile teaching and learning*. Berlin: Springer-Verlag.

Appendix A

Technology Science Teaching Efficacy Beliefs Survey

(Adapted from Bleicher, 2004; Wang et al., 2004)

Purpose: The purpose of this survey is to determine your beliefs and perceptions of using technologies in your science teaching. The use of technologies in science teaching is a broader term referring to, but not limited to, the use of mobile devices, such as laptops, iPads, tablets, iPods, and smart phones, or devices such as computers for various activities, such as internet searches, simulations, apps, software, and the development of PowerPoint presentations, to support teaching and learning in elementary science classrooms.

Please circle the choice that best matches the degree to which you agree with each statement below.

5 = Strongly Agree
4 = Agree
3 = Uncertain
2 = Disagree
1 = Strongly Disagree

	SA	**A**	**UN**	**D**	**SD**
1. I feel confident that I understand technologies well enough to maximize their use in my science classroom	5	4	3	2	1
2. I feel confident that I have the skills necessary to use technologies for science instruction	5	4	3	2	1
3. I feel confident that I can successfully teach relevant science content with the appropriate use of technology	5	4	3	2	1
4. I feel confident in my ability to continually find better ways to teach science using a variety of technologies	5	4	3	2	1
5. I feel confident that I can help students when they have difficulty with using technological devices during science instruction	5	4	3	2	1
6. I feel confident that I can effectively monitor students' use of technological devices during science instruction in my classroom	5	4	3	2	1
7. I will generally teach science effectively using technology	5	4	3	2	1
8. I feel confident that I can motivate my students to participate in science lessons using technology	5	4	3	2	1
9. I feel confident that I can mentor students in the appropriate uses of technology to learn science	5	4	3	2	1
10. I feel confident that I can consistently use technology in effective ways to teach science	5	4	3	2	1
11. I know the necessary steps to effectively teach science concepts using technology	5	4	3	2	1

12. I feel confident that I can regularly incorporate technologies into my science classes 5 4 3 2 1

13. I feel confident about assigning, grading and providing feedback on science projects using technologies 5 4 3 2 1

14. I feel confident about selecting appropriate technology resources, software and products to improve science instruction 5 4 3 2 1

15. I feel comfortable using technologies in my science teaching 5 4 3 2 1

16. I will be responsive to students' needs while teaching science using technology 5 4 3 2 1

17. When teaching science using technology, I will usually welcome student questions 5 4 3 2 1

18. I feel confident that as time goes by, my ability to address my students' needs for learning science using technologies will continue to improve 5 4 3 2 1

19. I feel confident that I can develop creative ways to teach science using technology 5 4 3 2 1

20. I will typically be able to answer students' science questions while they engage in learning science using various technologies 5 4 3 2 1

Appendix B

Item Statistics

Item	*Mean*	*SD*	*N*
1	3.97	0.74	67
2	4.01	0.80	67
3	3.55	0.91	67
4	3.58	0.98	67
5	3.92	0.89	67
6	4.04	0.71	67
7	3.63	0.76	67
8	4.28	0.62	67
9	3.91	0.79	67
10	3.81	0.84	67
11	3.0	0.95	67
12	3.72	0.79	67
13	3.94	0.92	67
14	3.34	0.98	67
15	3.83	0.86	67
16	4.39	0.55	67
17	4.57	0.58	67
18	4.66	0.54	67
19	4.15	0.80	67
20	4.10	0.74	67

Appendix C

Sample Interview Questions (Part I)

1. Do you see yourself as a science teacher using technology in your science classroom? Explain.

2. Did you take any science classes prior to entering college (high school)? Please summarize your experiences from those classes.

3. What kinds of technologies were used in your prior K-12 science classes?

4. Did you take any science classes before taking this physics content course in college? Please discuss your experiences from those science classes.

5. What kinds of technologies were used in your science courses in college?

6. Have you taught science before? If so, summarize your teaching experiences. Did you incorporate technology into your science instruction? If so, elaborate.

7. How confident do you feel in your preparation to teach the science content using mobile technologies? Rate your confidence on a scale of 1 to 5, with 1 being very low confidence and 5 being very high confidence. Explain why you selected a particular level.

8. What makes you feel confident that you can teach science using a variety of technologies?

9. What makes you question your ability to teach science using various technologies?

10. What kinds of mobile technologies do you have? Do you use them for academic purposes? If so, in what ways do you use technology? How often do you use technology for academic purposes?

11. What are your beliefs about using mobile technologies for science teaching?

12. What are some of the technologies you are using in your physical science course? In what ways do they influence your learning? In what ways do they influence your confidence to teach with technology?

13. (For the experimental group only) What are you using iPads for? How are you using those iPads? What specific tools are you using, if any?

Appendix D

Sample Interview Questions (Part II)
(**Some additional questions were designed only for the experimental group participants who experienced the Exploring Physics curriculum on iPads*)

1. Describe your experiences in this physics content course that have influenced your confidence to use technologies in your science instruction.
2. Do you think your confidence to teach with technology has changed over the semester? Explain.
3. How confident do you feel in your preparation to teach the physical science content that you learned in the course using technology? Rate your confidence on a scale of 1 to 5, with 1 being very low confidence and 5 being very high confidence. Explain why you selected a particular level.
4. What makes you feel confident that you can teach science using a variety of technologies?
5. What makes you question your ability to teach science using various technologies?
6. Did this physics content course prepare you for the challenges you may face when teaching science using technology? In what ways do you think the course prepared you? In what ways do you think the course did not prepare you?
7. What do you see as the benefits associated with using technology in science teaching and learning?
8. What do you see as the challenges associated with using technology in science teaching and learning?
9. Share your views about using mobile technologies in science teaching. What are the benefits? What are the challenges?
10. Do you think your beliefs about teaching science with technology have changed after exposure to the course? Explain.
11. Share your ideas about how you might use technology to teach science in your future classrooms.

*Additional questions for the experimental group

12. Describe what you liked about using iPads in class.
13. What aspects of using iPads influenced your confidence to teach science using technology?
14. Describe what you disliked about using iPads in class.
15. How was your experience working with iPads different from past science courses that you may have taken?
16. Did you face any problems/challenges in working with the Exploring Physics app?
17. What advantages or disadvantages do you see in using iPads in science classrooms? Relate your experiences in this content course.
18. Are there are aspects of the iPad or the app itself that influence your confidence to teach science? Explain.
19. What other specific tools did you use in the app? What other specific tools did you use on the iPads?
20. What other changes could be made to the app itself to improve your learning experience?