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Mobile apps for science learning: Review of research

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ABSTRACT

This review examined articles on mobile apps for science learning published from 2007 to 2014. A qualitative content analysis was used to investigate the science mobile app research for its mobile app design, underlying theoretical foundations, and students' measured outcomes. This review found that mobile apps for science learning offered a number of similar design features, including technology-based scaffolding, location-aware functionality, visual/audio representations, digital knowledge-construction tools, digital knowledge-sharing mechanisms, and differentiated roles. Many of the studies cited a specific theoretical foundation, predominantly situated learning theory, and applied this to the design of the mobile learning environment. The most common measured outcome was students' basic scientific knowledge or conceptual understanding. A number of recommendations came out of this review. Future studies need to make use of newer, available technologies; isolate the testing of specific app features; and develop additional strategies around using mobile apps for collaboration. Researchers need to make more explicit connections between the instructional principles and the design features of their mobile learning environment in order to better integrate theory with practice. In addition, this review noted that stronger alignment is needed between the underlying theories and measured outcomes, and more studies are needed to assess students' higher-level cognitive outcomes, cognitive load, and skill-based outcomes such as problem solving. Finally, more research is needed on how science mobile apps can be used with more varied science topics and diverse audiences.

1. Introduction

Mobile devices are becoming increasingly popular and connected with our daily lives. Each new version of these devices brings innovative features that make them more convenient and affordable, and new apps continually become available that make our lives easier. These advances have prompted educators and researchers to utilize these devices to promote teaching and learning. There is great potential in using mobile devices to transform how we learn by changing the traditional classroom to one that is more interactive and engaging (Shen, Wang, & Pan, 2008). It allows educators to teach without being restricted by time and place, enabling learning to continue after class is over or outside the classroom in places where learning occurs naturally (Huang, Lin, & Cheng, 2010). It also gives educators the ability to connect with learners on a more personal level with devices that they use on a regular basis (Ward, Finley, Keil, & Clay, 2013). Finally, sensing technologies enable learning to be personalized and customized to the individual learner (Chu, Hwang, Tsai, & Tseng, 2010).

Given the prevalence of mobile devices in education, research on mobile learning is rapidly increasing (Hung & Zhang, 2012; Hwang & Tsai, 2011; Wu et al., 2012) and thus has been reviewed in several studies (Cheung & Hew, 2009; Hung &

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Zhang, 2012; Hwang & Tsai, 2011; Hwang & Wu, 2014; Wu et al., 2012). Some reviews focused on specific aspects of mobile learning, such as mobile learning games (Avouris & Yiannoutsou, 2012; Schmitz, Klemke, & Specht, 2012), mobile computer-supported collaborative learning (Hsu & Ching, 2013), or mobile apps (Jeng, Wu, Huang, Tan, & Yang, 2010). Trends in the literature have also been reported across multiple reviews. For example, reviews have shown that mobile learning is highly motivating for students (Hsu & Ching, 2013; Hwang & Wu, 2014; Schmitz et al., 2012). On the other hand, some of the findings from these past reviews have been contradictory. For example, reviews reported mixed findings on the effect of mobile environments on learning outcomes. Hwang and Wu (2014) did a review on mobile learning studies spanning 2008–2012 from select journals and found that 83% of the studies that measured learning achievements reported positive outcomes. Similarly, Hsu and Ching (2013) reviewed studies on mobile computer-supported collaborative learning from 2004 to 2011 and reported that six of the nine studies found positive improvements in students' understanding and application of concepts. In contrast to these positive findings, Schmitz et al. (2012) reviewed studies on mobile games from 2001 to 2011 and found that there was not sufficient evidence on whether mobile games improved learning outcomes. Similarly, Cheung and Hew (2009) reviewed studies on mobile devices from 2000 to 2008 and found no significant differences in students' test scores for studies that compared mobile devices to equivalent paper-and-pencil treatments. They also reported that claims of enhanced learning were often not experimentally tested.

Although there have been several valuable syntheses of previous studies on mobile learning, there are areas that require further examination. For example, there is strong potential for using mobile learning in the area of science education due to a number of aspects that make it unique and well suited to the affordances of mobile technology. Much of science takes place outside of the classroom and is arguably better studied in its natural environment, while other science content is impossible to see with the naked eye and requires graphical visualizations for students to be able to fully understand it. In addition, scientific system models cannot be completely comprehended without an immersive experience that demonstrates how the variables interact. These distinct aspects of science learning are well aligned with the mobility of newer devices as well as their ability to display interactive, three-dimensional graphics and simulations. However, there have been no reviews of research conducted to date on mobile learning in science.

Furthermore, only a few studies reviewed the attributes or design patterns/features of mobile apps (Avouris & Yiannoutsou, 2012; Jeng et al., 2010; Schmitz et al., 2012), and two of these studies were focused specifically on games. Also, none of the studies on mobile learning thoroughly examined the specific theoretical foundations underlying the mobile learning research, although one review by Cheung and Hew (2009) noted that much of the research was not theoretically grounded. Given the mixed results on the effectiveness of mobile environments on learning outcomes, the potential of mobile learning in science education, and the absence of reviews focusing on design features and theoretical foundations of mobile applications, a review is needed to further examine the design and effectiveness of mobile applications being integrated into science education.

Based on the areas that need further examination, the purpose of this review of research is to provide an updated review of studies on mobile apps, specifically in the area of science learning. The analysis framework used to guide the review was the concept of grounded learning systems design, "a process that involves linking the practices of learning system design with related theory and research" (Hannafin, Hannafin, Land, & Oliver, 1997, p. 101). This framework provided a lens through which to examine the literature for the connections made between the theoretical foundations, its corresponding design principles and features, and the validated research outcomes (Hannafin et al., 1997). To apply this framework, the review examined the literature for its alignment of the mobile app's design features, the underlying theoretical foundations, and the resulting outcomes related to science learning, as well as discussed their interrelationship with one another. This framework formed the basis for the research questions for this review, which are as follows:

1. What is common to the mobile app design used in science mobile app studies including:
   a) the general app characteristics?
   b) the specific design features?
2. What are the theoretical foundations common to mobile app studies in science?
3. What are the measured outcomes related to science learning associated with mobile app studies in science?

2. Method

2.1. Article selection

To find articles for this review, the Web of Science (all databases) and SCOPUS databases were used to search for mobile learning in science education. The review covered articles published from 2007 (the introduction of the iPhone and other smartphones) to 2014. These databases were chosen because they are known for encompassing high impact, high quality journals indexed in the Science Citation Index and the Social Citation Index.[1] Both databases were searched with the same

[1] The methodology of article selection and analysis described here was adapted from a review of game-based learning in science conducted by Li and Tsai (2013).