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Mobile augmented-reality artifact creation as a component of mobile computer-supported collaborative learning

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ABSTRACT

This exploratory study examined the effectiveness of smartphone-based, AR artifact creation and other mobile collaborative learning activities in reinforcing the technological pedagogical content knowledge (TPACK) of pre-service teachers. Adopting a mixed-method research design, the study indicated that mobile AR artifact creation with peer discussion tended to better promote the componential competencies of technological pedagogical knowledge (TPK) and the integrative development of technological pedagogical content knowledge *(*TPACK), whereas mobile media artifact viewing with peer discussion seemed to better support the content knowledge (CK) development.

1. Introduction

Similar to the vast potential of leveraging mobile technologies for learning with augmented reality, there is great opportunity of applying mobile technologies in the context of collaborative learning (Hsu & Ching, 2013; Laurillard, 2009; Stahl, Koschmann, & Suthers, 2006). Based on Vygotsky's sociocultural theory (Vygotsky, 1978), social environment is critical in individuals' development and learning. By integrating the emerging mobile applications into a mobile-friendly web conferencing platform, it is possible to structure a mobile computer-supported collaborative learning environment that helps students engage in active knowledge construction.

Because of the advancing and readily available mobile technologies, some unique interaction experiences such as mobile augmented reality (AR) can be integrated into the collaborative learning environment to promote a situated learning experience. Mobile AR is a promising tool for teaching and learning because of its ubiquitous availability and the strong computing power built into ultra-portable devices (Hsu, Ching, & Snelson, 2014). Dunleavy and Dede (2014) categorized mobile AR into two types: Location-aware AR and vision-based AR. Both types of mobile AR support the situated and immersive perception of a complex concept (or process) by relating real-world objects and "virtual" digital information. Vision-based AR presents the media to learners when they point the camera in a mobile device to certain objects (e.g., QR Code, images). In this study, we employed vision-based AR via Aurasma. This application allows learners to first *create* instructional videos and animations as virtual information artifacts associated with an everyday object or phenomenon, and then *share and review* these multimedia information artifacts (called Aura) with peers when they point their in-device camera to the designated or tagged objects.

Existing literature on using text-based discussion forums has indicated its inadequacy in enabling information search and synthesis, social-cultural relationship development, or multimodal communication (Ke & Chávez, 2013). Emerging web conferencing technology, such as VoiceThread, can act as a multimodal, *mobile-accessible* alternative for asynchronous discussion forums. VoiceThread (VT) is a web-based application that allows learners to place collections of media like images, videos, and documents at the center of an asynchronous discussion, and enables commenting using a mix of text, audio, and video recordings (Ching & Hsu, 2013). In spite of its promise in affording a multimodal and media-centric interaction, research on using VT in the setting of computer-supported collaborative learning is lacking (Ching, 2014).

Constructionism and enactivism learning theories argue that learners actively construct knowledge out of their experiences, especially when they are engaged in building objects (Kafai, 1995; Li, 2012; Papert, 1980). Situating such a learning-by-making approach in the collaborative learning context, the activities of AR artifact creation, sharing, and VT-based peer critique can engage participants in constantly articulating, checking, and constructing content-specific mental models. Simultaneously, educational AR creation and VT-based peer critique can act as meaningful events of technology-supported learning and support technological understanding in an activity-based, pragmatic way. They should potentially promote the integrated development of content and educational technology skills, which compose an essential competency for teaching and learning in the 21st century (Finger, Jamieson-Proctor, & Albion, 2010). The exemplification of such a

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content-based technological competency in the education setting is the technological pedagogical content knowledge (TPACK) (Koehler & Mishra, 2009).

TPACK is considered the specialized, highly applied knowledge that is "situated, event-structured, and episodic" and hence not easily learned or taught (Harris & Hofer, 2009, p. 4087). Research exploring the ways to help students to build and use TPACK is still at an early stage. Among the early efforts, learning by developing (or making) technology-integrated instructional artifacts is an approach found promising for TPACK development (Harris & Hofer, 2011; Koehler, Mishra, & Yahya, 2007). Educational AR artifact creation with collaborative review/critique can act as a mobile-accessible technique of the learning-by-making approach for TPACK.

Therefore, in this exploratory study we examined the effectiveness of smartphone-based collaborative learning activities, comprising augmented reality (AR) artifact creation and VT-based discussion, in reinforcing the technological pedagogical content knowledge (TPACK) of teacher education students or pre-service teachers. Particularly, two research questions were addressed: (1) Will participating in mobile AR artifact creation with peer discussions, in comparison with mobile media artifact viewing with peer discussions, better improve the TPACK of teacher education students? (2) What features of the mobile-accessible learning tools support collaborative learning for TPACK development?

2. Literature review

2.1. Mobile augmented reality for learning

Augmented reality (AR) refers to the combination of virtual, overlaid information (e.g., text, images, video clips, sounds, 3-dimensional models, & animations) with real world objects to enhance the user's learning about and the interaction with the physical environments. For example, a location-based AR mobile app, Wikitude, leverages the built-in GPS in mobile devices to track a user's real world location and present contextually relevant virtual data of the surrounding landmarks (e.g., buildings, parks, and stores). AR applications can also work without location restriction and utilize real world images and objects as "triggers" to activate digital information overlay to support learning. For example, the Aurasma app allows its users to view "Aura" – a multimedia artifact that can be an animation or a video clip – by pointing their mobile devices to a designated real-world trigger. Aurasma users can create their own Auras to anchor virtual multimedia overlays in real-world objects, by choosing or capturing an image as the activator and then connecting it with a pertinent animation or video. The user-made Auras can later be published and shared with others through the mobile Aurasma social network; a shared Aura will be presented once a mobile device identifies the trigger image.

The vision-based, digital-authorship-oriented mobile AR application holds great potential for educators because it provides learning that is active, contextually relevant, and closely and immediately related to the learners' environment (Billinghurst, Kato, & Poupyrev, 2001; Bower, Howe, McCredie, Robinson, & Grover, 2014). Yet compared to location-based mobile AR applications and studies (e.g., Dunleavy, Dede, & Mitchell, 2009; Huizenga, Akkerman, Admiraal, & Dam, 2009), studies of vision-based mobile AR are relatively few. In a recent review, Cheng and Tsai (2013) reported that vision-based AR promotes spatial ability, practical skills, and conceptual understanding in science education. In a study by Bressler and Bodzin (2013), middle school students collaboratively played an inquiry-based mobile AR game by using mobile devices to scan QR (quick response) codes to access game-related information, solve a detective case, and learn forensic science. The study reported that the group play of the vision-based AR game can increase students' science interest and their collaboration skills. In another study, Furió, González-Gancedo, Juan, Seguí, and Costa (2013) also utilized vision-based AR to present science information to school students (aged 8 to 10), by using a selection of pictures as "markers" in a classroom to activate multimedia presentations on the related content topics. Furió et al. (2013) reported that the size and weight of mobile devices did not influence students' acquired knowledge, engagement, satisfaction, ease of use, or AR experience.

It should be noted that prior research on mobile AR, including the aforementioned studies, generally focuses on information provision and overlay as the major functions of mobile AR applications. Hence learning is mainly the collection and comprehension of pre-packaged information. Such an AR-based learning experience, as argued by Bower et al. (2014), may fail to support "higher order integrative thinking skills such as analysis, evaluation, and creation" (p. 4). Although recent mobile AR applications (e.g., Aurasma) encourage digital authorship, research on the practice of making learners designers with mobile AR is lacking. Besides, prior research of mobile AR generally focused on K-12 school students. Research on the pedagogical applications of vision-based mobile AR in higher education, especially for pre-service teachers who are in need of pedagogical and technological knowledge of augmented reality, is warranted.

2.2. Mobile CSCL

Mobile computer supported collaborative learning (MCSCL) refers to the practice of meaning making by groups of individuals in the context of joint activity that is mediated through mobile computing (Stahl et al., 2006; Zurita & Nussbaum, 2004a, 2004b). In a recent review of empirical studies on MCSCL, Hsu and Ching (2013) found multiple ways in which mobile computing mediates meaning making in a joint activity. Particularly, wirelessly interconnected mobile devices can: 1) facilitate information sharing and instant feedback provision (e.g., Zurita & Nussbaum, 2004b); and 2) provide individuals with different portions of a group learning task and coordinate task-oriented interaction (e.g., Boticki et al., 2011; Roschelle et al., 2009).

Most of previous studies of MCSCL were conducted in K-12 settings. For example, in the work of Zurita and Nussbaum (2004a, 2004b) that focused on reading literacy and numeracy, mobile devices enhanced face-to-face collaborative learning activities by enabling digital information sharing, providing instant feedback on individual and group's task performances, and facilitating first-graders' collaborative knowledge construction and internalized individual understanding. Boticki et al. (2011) helped primary school students in Singapore learn mathematics by using wirelessly connected mobile devices to support student-led, emergent learning groups. Via mobile devices, students reviewed fractions presented on the screen, identified peers with complementary fractions, and sent group invitations to peers to form a group and complete the task of fraction adding. The work of Boticki et al. (2011) is in line with that of Roschelle et al. (2009), who also used mobile devices to present multiple portions of a fraction problem to students in a learning group to activate peer discussion and collaborative problem solving.

Although there is empirical evidence suggesting that learners actively participate in mobile collaborative learning activities, research on creation-oriented, design-based mobile collaborative learning is lacking. In the studies reviewed, learning content was generally delivered to learners, which falls short of the Web 2.0 spirit that encourages and empowers learners to create, share (what they created), and communicate (about what they created) through the Web, especially the mobile Web. Prior research on MCSCL also lacks studies that use mobile-accessible, multimodal social media (e.g., VoiceThread) to promote interaction, and studies that expand the context to higher education (Hsu & Ching, 2013).

2.3. Learning by making

Dewey (1958) argued that knowing and doing are tightly associated, and as a result, learning needs to take place in the context of activity and