



Collaborative science learning in an immersive flight simulation



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ABSTRACT

This mixed methods study examined the effect of Astronaut Challenge, an immersive, flight-simulation-based learning program, on the collaborative learning process and science knowledge development of high-school students. The study findings suggested that simulation-based collaborative learning activities significantly promoted students' scientific understanding about the dynamics of the space flight system. The knowledge test and STEM attitudes survey results did not indicate a significant difference between two immersive contexts of the simulation (exclusive-space flight simulation versus classroom flight simulation) in influencing the learning outcomes. Qualitative findings suggested that the higher level of the sensory immersion in a simulation-based learning environment may foster task engagement and procedural practice but not collaborative conceptual processing.

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1. Introduction

Immersion is a salient feature of the simulation-based learning environment. According to Dede (2009), immersion refers to “the subjective impression that one is participating in a comprehensive, realistic experience” (p. 66). It can be interpreted as a psychological experience that one perceives regarding how much s/he is attached to a learning environment, which can be provided via an active and dynamic interaction between the learner and their environment, sensory information in the 3D digital space, and authentic scenarios or tasks that tap into the learner's life experiences (Baños et al., 2004; De Freitas, Rebolledo-Mendez, Liarokapis, Magoulas, & Poulovassilis, 2010; Dede, 2009). Studies have shown that immersive digital simulations, delivered via a computer-assisted simulator or a virtual reality, can enhance education by allowing multiple perspectives, situated learning, and transfer (e.g., Dunleavy, Dede, & Mitchell, 2009; Freitas & Neumann, 2009; Hansen, 2008). However, research on the effects of immersion on collaborative learning processes is still limited and the result is inconclusive. Research is also needed on the learning benefits and preferences that different levels of immersion in the digital space of a simulation cultivate for a diverse learner group, which guides the instructional arrangement of interactive media in a simulation-based collaborative learning environment.

Prior research suggested that immersive, participatory simulation is an emerging and a prominent learning tool to help learners understand a complex, dynamic science system (Barab & Dede, 2007; Colella, 2000). Learning about complex

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systems is difficult because complex systems aggregate multiple components that interact with each other in multiple levels (Hmelo-Silver & Azevedo, 2006). Sterman (1994) argued that approaches to learning about complex dynamic systems require tools to frame issues and elicit/create an iterative feedback-based learning cycle, and methods to improve group or team processes that will overcome defensive routines for individuals and sharpen their scientific reasoning skills. Based on such a perspective, it is warranted to examine the capabilities of digital immersive simulations in promoting collaborative learning and hence understanding about a complex, science system (such as the engineering system of a space flight).

Therefore, in this study we examined the design and effect of an immersive, simulation-based science learning program on the collaborative learning process and science knowledge development of high-school students. The major research question are: (a) What is the impact of a space flight simulation program on high school students' collaborative learning processes, their science knowledge, and positive disposition development? (b) Is there a differential effect of the immersive contexts of this simulation-based learning environment on the collaborative learning process and outcome?

2. Literature review

2.1. Immersive simulation and collaborative learning

It is asserted that simulation-based experiential and inquiry learning is a basic form of computer supported collaborative and constructive learning (O'Malley, 2012; Van Joolingen et al., 2005). Immersive simulations, in addition, will extend the computer-supported simulation from the computer screen to a surrounding microworld in which participants collaboratively role play, experience, and explore the dynamics of the simulated system (Colella, 2000). It is expected that immersive simulation will create a context or *space* within which participants can experiment with concepts as “an abstraction” from a sensory-motor experience (Pufall, 1988, p. 29). A potential benefit of immersive simulation is to stimulate intellectual curiosity by enabling learning interactions in real, physical space, thus engaging them in deep reasoning about the underlying structure of the simulation (Klopfer, Yoon, & Perry, 2005; Roschelle, 2003). It is also advocated that artifacts in an immersive simulation can act as shared representations and hence an effective representational tool to facilitate collaborative knowledge construction (Lin, Duh, Li, Wang, & Tsai, 2013).

On the other hand, empirical research examining immersive simulation and collaborative learning is limited. In a qualitative study, Colella (2000) examined a collaborative, participatory simulation of disease transmission in which students, via wearable computing, role-played agents conveying epidemic viruses in a life-sized microworld. She reported that learners displayed a robust and persistent level of immersion during the simulation activity. She also found that integrating the direct experience of a scientific phenomenon into the students' interpersonal space had enabled students to develop scientific inquiry skills, such as problem identification, hypotheses construction, and experimental design. Leemkuil, de Jong, de Hoong, and Christoph (2003) conducted a formative evaluation of a web-based, collaborative simulation game focusing on knowledge management (KM). Learners role-play in group as members of a virtual KM team to solve KM problems in a business, via both asynchronous and synchronous online communication tools. The study reported that participants' awareness of presence and peers' activities (called ‘workspace awareness’) mediated the collaborative learning process in the simulation. In a recent mixed-method study, Lin et al. (2013) compared the effectiveness of a mobile, collaborative augmented-reality (AR) simulation with a traditional 2D simulation in assisting task-oriented, physics knowledge construction for students in dyads. They reported that the learners using the AR-supported immersive simulation showed significantly better learning achievements, including knowledge test performance and the frequency of knowledge construction behaviors, than those learning with the 2D simulation.

2.2. Role of immersion in simulation-based learning

According to Murray (1997), immersion is a participatory activity associated with a psychological experience of being transported to an elaborately simulated place. Dede (2009) synthesized the literature and reported that immersion draws on sensory, actional, and symbolic facets (p. 66). Sensory immersion refers to the replication of the sensory interfaces of a three-dimensional space (e.g., audio, visual, and haptic experience). Actional immersion involves the engagement of the participants in simulated actions. Symbolic immersion triggers psychological associations (e.g., stress and fear) via the content of an experience. The salient factor that creates those three types of immersion in simulation is fidelity – the extent to which the simulation emulates the real world (Hays & Singer, 1989, 2012). Correspondingly, fidelity comprises physical, functional, and psychological facets. Physical fidelity refers to the degree to which the visual displays, audio, and instrument operation looks, sounds, and feels like the real operational environment; functional fidelity is the degree to which the tasks and interactions executed by the learners emulate the real operation; and psychological fidelity is the degree to which the simulation replicates psychological experiences in the real-world environment (Alexander, Brunyé, Sidman, & Weil, 2005; Hays & Singer, 2012).

Prior research on the simulations for learning suggested that an immersive work space crafted by a high fidelity simulation will enable learners to simultaneously process both 2D and 3D information (Febretti et al., 2013) and to better engage in inquiry learning through multiple perspectives (Dede, 2009). It is argued that immersion and fidelity evoked via a *surrounding* context, especially that replicates the interactivity and the psychological experience, will improve learning transfer from the simulation to the real world (Alexander et al., 2005). Furthermore, the theory of identical elements proposed that effective transfer between simulated and real environments occurs only when the simulated and real tasks have similar logical or deep structures rather than common surface elements (Chase & Ericsson, 1982; Lehman, Lempert, & Nisbett, 1988; Thorndike,

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