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Motivation and beliefs about the nature of scientific knowledge within an immersive virtual ecosystems environment

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ABSTRACT

We explored Grade 6 students' ($n = 202$) self-efficacy, epistemic beliefs, and science interest over a 10-day virtual ecology curriculum. Pre- and post-surveys were administered, and analyses revealed that (1) students became more self-efficacious about inquiring scientifically after participating in the activity; (2) students on average evinced a shift toward more constructivist views about the role of authority in justifying scientific claims; (3) students who identified more strongly with being a science person evinced greater gains in self-efficacy, developed a less constructivist view about the role of authority in justifying claims, and became more interested in science overall; and (4) students who held an incremental theory of ability evinced greater gains in self-efficacy. We discuss the implications of these findings for science educators and instructional designers in the design and use of immersive virtual worlds for middle school science students.

1. Introduction

Much research has shown that science is often considered more confusing and more difficult than other academic subjects (Britner, 2007; Cleaves, 2005; Dweck, 2007; National Academies of Science, 2011). Furthermore, in the context of the current educational climate in which such a high premium is put on students' performance on standardized tests, teachers have little time to allow their students to explore science concepts in interesting ways, thereby contributing to students' perception of science as dull. This struggle to motivate students presents a significant challenge especially during the middle school and high school years, when there is a marked general decline in motivation (Eccles et al., 1983).

In addition to motivating students to do well in science, another major goal of science reform is to advance students' beliefs about the nature of scientific knowledge and knowing (National Academy of Sciences, 2011; National Research Council, 2000; National Research Council, 2007). The more recent work on these beliefs, called *epistemic beliefs*, has examined relations between the construct and other facets of cognition like motivation and self-regulation (Buehl & Alexander, 2005; Muis, 2004; Tsai, Ho, Liang, & Lin, 2011). Less attention, however, has been directed toward how epistemic beliefs change over short periods of time, especially with instructional interventions designed to tap students' epistemic beliefs.

Finally, innovative technologies have been receiving a considerable amount of attention as a way to motivate students, and to provide students with science inquiry experiences that both make learning interesting and provide life-like simulations of what real scientists do. However, despite the widely accepted notion that technology-based activities are inherently motivating, the evidence regarding their motivational effectiveness is mixed (Moos & Marroquin, 2010). For example, as Moos and Marroquin noted, some research has shown that computer-based instruction increased students' interest in the material. But other research has shown that there are a number of variables, such as prior knowledge, that modify the relationship between participation in technology-based activities and students' motivation.

Another reason for these mixed findings could be the way that many researchers exploring educational technologies have conceptualized motivation—as a broad *unidimensional* construct. However, motivation is multifaceted in that some students may find an activity to be very interesting and enjoyable (i.e., high interest value beliefs) but not consider themselves competent enough to do well (i.e., lack self-efficacy). In fact, even in a recent meta-analysis, Wouters et al. (2013) adopted a broad view of motivation, yet reported findings on the overall construct of motivation without discussing which aspects of motivation seemed to be

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affected by participation in technology and which aspects did not. Thus, research regarding the motivational affordances of technology should be based firmly in well-studied theories of motivation that treat motivation as a multidimensional construct (Chen, Zap, & Dede, 2013; Moos & Marroquin, 2010).

Given the above, three main objectives guided the present study. First, because some have begun to question the truism that technology is inherently motivating, we explored the effect of participating in an inquiry-oriented virtual environment on students' *interest* in science and their confidence in being able to conduct scientific inquiry to solve a complex problem (i.e., students' *self-efficacy* for scientific inquiry). Second, because the virtual environment was also designed to tap students' beliefs about the nature of scientific knowledge—their *epistemic beliefs*—we explored the effect of participating in the virtual environment on students' epistemic beliefs. Third, because numerous variables modify the relationship between participation in technology-rich activities and motivational outcomes, we sought to examine psychological moderators of this relationship. In particular, some researchers have shown that certain core assumptions can foster a framework for how students engage with their environment. The first core assumption we investigated was students' theory of ability as either static (*fixed theory of ability*) or as malleable with effort (*incremental theory of ability*; Dweck, Chiu, & Hong, 1995). The second core assumption we studied was students' *science identity*—beliefs about the extent to which individuals identify with scientists and their work (Estrada, Woodcock, Hernandez, & Schultz, 2011; Hernandez, Schultz, Estrada, Woodcock, & Chance, in press; Pugh, Linnenbrink-Garcia, Koskey, Stewart, & Manzey, 2009). In the present investigation we explored whether students' theory of ability and their science identity modified the effect of the intervention on students' self-efficacy, interest, and epistemic beliefs in science.

2. Theoretical framework

2.1. Science self-efficacy

Bandura (1997) defined self-efficacy as beliefs in one's capabilities to learn or perform a task at a specified level of competence. Self-efficacy has been shown to affect how productively individuals think, how well they motivate themselves, how long they persist in the face of failures, and ultimately what and how much they achieve (see Pajares & Urdan, 2006 for a review). In the domain of science, self-efficacy is related to how interested adolescents are in science, the types of goals they set for themselves, their level of achievement, as well as their persistence in pursuing science-related college majors and careers (Andrew, 1998; Beghetto, 2007; Britner & Pajares, 2001, 2006; Chen & Pajares, 2010; Gwilliam & Betz, 2001; Lau & Roeser, 2002; Lent, Brown, & Larkin, 1984; Luzzo, Hasper, Albert, Bibby, & Martinelli, 1999).

Given the crucial role self-efficacy has been shown to play, researchers have recently become interested in the various ways that self-efficacy can be formed. Bandura (1997) hypothesized that self-efficacy is formed by how people interpret information from four sources. The primary source is how one interprets past performances, or *mastery experiences*. For example, in science, as students engage in science-related tasks and activities, they interpret how successful they are from these experiences and form conceptions about how capable they are in engaging in subsequent science-related tasks and activities.

Self-efficacy is also influenced by watching the successes and failures of similar others. These *vicarious experiences* can be especially powerful when the role models whom an individual observes are perceived as being very similar to oneself. Next, teachers, parents, and classmates often send individuals messages, either verbally or through other indirect ways of communicating, about whether they think an individual can succeed. These *verbal and social persuasions* can be especially influential when they come from sources that an individual trusts. Finally, anxiety, joy, fatigue and other *physiological and affective states* serve as the fourth and final source of self-efficacy. How students interpret information from this source can often signal to students how competent they are (Bandura, 1997).

Can immersive technologies target these sources to bolster students' self-efficacy? Some researchers have shown that such an endeavor is possible (e.g., Hsieh, Cho, Liu, & Schallert, 2008; Ketelhut, 2007; Moos & Honkomp, 2011; Rosenberg-Kima, Baylor, Plant, & Doerr, 2008). For example, Rosenberg-Kima et al. (2008) used an on-screen avatar that appeared similar and approachable to students to converse with students about the value of engineering careers. This visibly similar avatar was found to be effective at increasing the self-efficacy, interest, and utility beliefs of students in science and engineering courses.

Ketelhut (2007) also showed that students' pre-intervention self-efficacy for scientific inquiry was related to students' initial behaviors within a virtual world. However, after a number of visits to the virtual world, pre-intervention self-efficacy did not appear to affect students' behaviors. She hypothesized that one reason why exposure to the virtual world may have nullified the effects of initial self-efficacy is because students were able to take on the identity of a scientist (in the form of an avatar) and possibly benefit from the vicarious experiences of seeing oneself succeed in doing science. This hypothesis represents one promising aspect of immersive technologies—the ability to use virtual role models to convey important information for learners, thereby targeting their vicarious experiences.

2.2. Interest

In addition to beliefs about competence, students can hold beliefs about the value of science. According to Eccles et al. (1983), these beliefs about the value of an activity can have a substantial impact on students' willingness to participate in that activity. Within Eccles et al.'s expectancy-value framework of motivation, we focus specifically on the *interest value* component because of its germaneness to technology-rich activities. Students' *interest value* describes the enjoyment that one gains from doing a task. This particular dimension of the expectancy-value framework is relevant for participation in technology-rich activities because technology can spark students' initial interests in participating in an activity (Blumenfeld, Kempler, & Krajcik, 2006). That is, these activities can serve as an initial "hook" for students to continue engaging in a learning task. Numerous studies have also found that interest value is an important factor as students make decisions about choosing careers in Science, Technology, Engineering, and Mathematics (STEM; Lent, Lopez, Lopez, & Sheu, 2008; Lent, Paixao, da Silva, & Leitao, 2010). Interest value also is related to students choosing to take classes related to STEM fields (Watt, Eccles, & Durik, 2006).

How might technology-rich activities help support students' evolving interests in science? Some scholars have argued that technology-rich activities can be used to develop students' interest in subject matter by making the learning goals relevant and meaningful (Gee, 2003; Squire, 2003). For example, users of a 3-D immersive virtual world called *Quest Atlantis* assume the role of someone consulting a fictional Council to rebuild an arch that was destroyed by rulers of a fictional world. When learning goals are put within such a context, the learning goals themselves become interesting. Barab, Dodge, Jackson, and Arici (2003) found that when students completed quests within the *Quest Atlantis* context they completed significantly more quests and rated them