Iyer, S. et al. (Eds.) (2022). Proceedings of the 30th International Conference on Computers in Education.
Asia-Pacific Society for Computers in Education

The Role of Epistemic Curiosity in A 3D Virtual Game for Science Learning

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Abstract: In this study, we developed a three-dimensional virtual game to help students understand the concepts of evaporation and condensation. Next, we developed a research model to examine the relationships between epistemic curiosity, situational interest, learning engagement, and science achievement. Finally, we investigated the mediating role of situational interest in the proposed model. To this end, we will collect data from approximately 75 6thgrade students in Taiwan. We will analyze the results of the measurement model, as well as the underlying structural relationships, through PLS-SEM.

Keywords: epistemic curiosity, situational interest, engagement, science achievement

1. Introduction

Game-based learning (GBL) is defined as learning by accomplishing tasks or solving problems through games. Students may create strategies for solving problems or understanding complex systems while playing (Prensky, 2001). Several studies have demonstrated the positive effects of implementing GBL in science education, such as improvements in students' learning motivation (Chen, 2019), engagement (Eltahir et al., 2021), and performance (Lei et al., 2022).

With recent advances in technology, games can be played in new forms, such as virtual environments. Virtual environments provide three significant features: a three-dimensional (3D) space, a first-person view, and an interactive environment (Franceschi et al., 2009). 3D virtual environments can also be regarded as desktop virtual reality (VR) (Makransky & Petersen, 2021). 3D virtual gaming has been confirmed to improve students' learning motivation (Makransky & Petersen, 2019) and content knowledge (Liu, Li, & Ji, 2022). Thus far, few studies have highlighted the underlying relationships between affective factors and students' learning outcomes, such as engagement and achievements, in the context of emerging technologies (Lee et al., 2022).

In this study, we have developed a 3D virtual game to help students understand the concepts of evaporation and condensation at the elementary school level. Although evaporation and condensation are essential concepts in science education, elementary students tend to have alternative conceptions and consequently may find it difficult to differentiate between the two concepts (Tytler, 2000). We also developed a hypothesized model examining whether epistemic curiosity and situational interest can predict students' learning engagement and science achievement within a virtual reality game environment (Cheng, Lee, Hsu, 2022).

1.1 Epistemic Curiosity (EC)

Berlyne (1954) first proposed and conceptualized epistemic curiosity (EC), indicating that simulating curiosity and experimental spirit may promote intellectual development and academic achievement. Scholars further described EC as the desire to acquire intellectual information due to the knowledge gap (Loewenstein, 1994) and the demand of exploring an academic environment (Grossnickle, 2016). EC may prompt people to learn new things to reduce their knowledge gaps (Litman, Hutchins, & Russon, 2012).

Litman (2008) suggested that EC includes two types of personality traits: interest-type (I-type) and deprivation-type (D-type). I-type EC occurs when people learn new information to satisfy their inner joy, and students with I-type EC tend to take pleasure in seeking new information (Litman, 2010). The intention to minimize information deprivation may cause people to develop D-type EC, which is related to negative emotions concerning the lack of required information, and relief after the information is obtained (Grossnickle, 2016). Students with D-type EC may experience uncomfortable "need to know" feelings, and a desire to reduce the feeling of uncertainty (Litman & Jimerson, 2004; Litman & Spielberger, 2003). I-type EC is considered to be related to interest and the joy of discovering new information, whereas D-type EC correlates to negative emotions such as anxiety and anger (Litman & Spielberger, 2003).

Studies have considered EC a variable of personal traits and conducted research in the fields of online (Fang et al, 2019) and game-based (Hwang et al., 2019) learning. Consequently, EC was found to be related to learning behavior such as online help-seeking (Cheng, 2019). Hong et al. (2019) found EC to positively affect learning performance; the same results were subsequently confirmed by Hong et al. (2020). Huck et al. (2020) found that I-type EC significantly affects students' cognitive engagement and motivation during GBL.

There is still a lack of research associating students' EC with other affective factors or learning outcomes (Lee et al., 2022). Arnone et al. (2011) also suggested investigating relationships between curiosity, interest, and engagement in technology-based learning. Accordingly, they developed theoretical models to explain how people learn.

1.2 Situational interest (SI)

Interest is considered a psychological phenomenon that arises from an individual's intentional involvement in a particular object, activity, or event (Pintrich & Schunk, 2002). According to Schiefele et al. (1992), interest can be categorized as personal interest (PI) or situational interest (SI). PI refers to a preference for an activity based on prior experiences, whereas SI refers to the affective perception acquired from interacting with the activity or environment (Schiefele et al., 1992).

Studies have shown that students' SI may be improved by technology-assisted environments, such as multi-user VR (Chen et al., 2016) or gamification design (Bressler et al., 2021), and augmented reality (Chen & Liu, 2020). Notably, most studies examined interest stemming from technology through one construct of SI. Nevertheless, researchers have suggested that it may be useful to examine multi-dimensional constructs (Deci, 1992).

Chen, Darst, and Pangrazi (1999) indicated that SI encompasses several concepts: novelty, challenge, attention demand, instant enjoyment, and exploration intention. Novelty refers to students' responses upon perceiving the gap between known and unknown information. Challenge refers to students' perception of a task's difficulty when compared against their abilities. Attention demand refers to students' attention and mentality during the activity. Instant enjoyment refers to the satisfaction that students gained from the activity, which compelled them to continuously participate.
Exploration intention refers to students' intentions to explore.

Studies have shown that enhancing novelty and exploration intention may improve the experience of instant enjoyment, and further activate SI (Chen et al., 1999). Virtual technology has been confirmed to foster students' SI, especially the novelty and challenge perceived while library touring (Lin et al., 2021).

1.3 Engagement

Engagement is defined as the observable and unobservable identity of the interactions between students and learning activities (Deci & Ryan, 2000). Since engagement represents students' needs and willingness to participate in the learning process, it directly correlates to higher levels of learning (Bomia et al., 1997). As learning engagement gradually received more attention over the past 20 years (Trowler, 2010), scholars and practitioners have come to recognize it as an important theoretical and practical cornerstone for school completion (Perdue, Manzeske, & Estell, 2009). Prior studies also indicate that academic emotion is an important variable, which may mediate the relationship between learning motivation and engagement. Accordingly, researchers have suggested further focusing on academic emotion in the future (Pekrun, Elliot & Maier, 2009).

Engagement is generally considered in terms of three dimensions: cognitive, emotional, and behavioral (Fredricks, Blumenfeld, & Paris, 2004). Cognitive engagement is defined as the effort tounderstand learning content, including self-regulation and meta-cognition. Emotional engagement is defined as the emotional response toward people, activities, and learning content. Students may experience varying emotions, such as happiness, frustration, and boredom. Behavioral engagement is defined as the observable behavior corresponding to academic achievements, such as course participation (Fredricks et al., 2004). Although both cognitive and behavioral engagements encompass actions taken by students, cognitive engagement refers to mental effort, which is less likely to be measurable by direct observation (Henrie, Halverson, & Graham, 2015).

Although student disengagement is a common problem in education (Drigas et al., 2014), simulation games have been confirmed to increase student engagement (Hamari, Koivisto, & Sarsa, 2014). Studies have also found a positive correlation between student engagement and learning achievement (Kinzie, 2010). Liu et al. (2020) investigated differences in learning engagement between VR and conventional classroom environments. The results showed that students using VR exhibited significantly higher learning achievement and engagement than students in a conventional classroom.

1.4 Hypothesized model and research purpose

In this study, we hypothesized that students' EC can directly and indirectly predict their engagement and learning achievement through SI (Figure 1). Recent studies have verified the associations between learning traits and engagement. Cheng (2020) found that EC (particularly I-type) may positively and significantly influence SI, especially novelty and exploration intention. Vracheva, Moussetis, & AbuRahma (2020) found that EC is positively correlated to and may accurately predict learning engagement. Cheng (2021) found novelty, instant enjoyment, and exploration intention to positively affect students' learning behavior. Studies have also shown SI to positively increase learning engagement in remote education (Sun & Rueda, 2012), and through a refutational test (Thomas & Kirby, 2020). Furthermore, SI has been suggested to be a mediator in the relationship between individual difference variables and academic performance (Bråten et al., 2014). Makransky and Pertersen (2021) also suggested exploring how SI factors mediate the relationships between virtual learning experiences and learning outcomes. Cheng et al. (2022) confirmed that EC may accurately predict SI and attitudinal learning, and the results of their study also demonstrated the importance of novelty, instant enjoyment, and exploration intention in this context.

Based on the aforementioned studies, three goals were formulated for this study:

(1) To develop a 3D virtual game to help students understand the concepts of evaporation and condensation.
(2) To explore relationships between EC, SI, engagement, and science achievement in DGBL.
(3) To explore the mediating effect of SI in the proposed model.

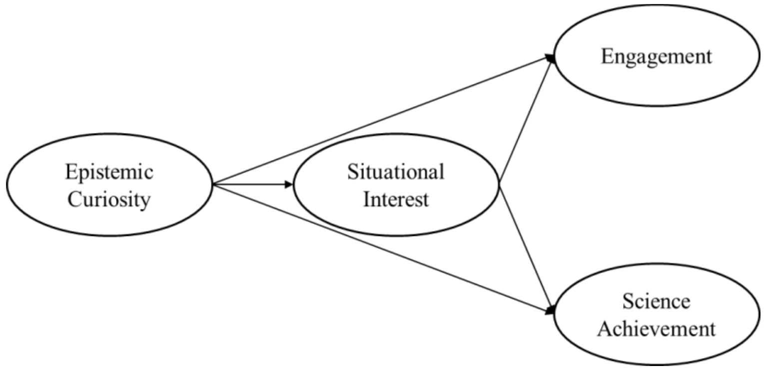

Figure 1. Hypothesized model showing relationships between epistemic curiosity, situational interest, engagement, and science achievement.

2. Method

2.1 Learning materials

We developed a 3D virtual game, Water in the House, designed for elementary school students (5th-6th grades) to learn the concepts of evaporation and condensation and locate objects associated with these phenomena in a virtual house. All objects in the house are based on real-life situations, enabling students to learn the underlying concepts through attempting and reflecting upon appropriate tasks (Kolb, 2014). In accordance with Sandberg, Maris, & Hoogendoorn (2014), we implemented GBL elements such as goals, challenges, and a leaderboard in our game. The game is displayed on a computer and allows players to freely explore the four rooms of the house by operating the keyboard and mouse.

2.2 Participants and procedure

We will collect data from approximately 75 6th-grade students in Taiwan. Students will complete a pre-test to assess their understanding of evaporation and condensation, as well as their EC scale, before playing the game for a maximum of 25 min. Subsequently, students will complete a post-test and post-survey to measure their SI and learning engagement.

2.3 Instruments

Three questionnaires were designed to test students' EC, SI, and engagement. Pre-test and post-test items were developed to measure the students' understanding of evaporation and condensation.

2.3.1 Questionnaires

The EC scale, adopted from Litman (2008), encompasses I-type (five items) and D-type EC (five items). I-type EC, defined as the satisfaction of discovering new information, includes items such as "I enjoy exploring new ideas." D-type EC, defined as the desire to eliminate uncertainty, is characterized by items such as "I spend hours on a problem because I cannot rest without an answer." Participants responded on a Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Past research has reported good reliabilities (I-type: $\alpha = 0.82$; D-type: $\alpha = 0.76$), with a moderate positive correlation ($r = 0.47$) between the two factors (Litman, 2008).

The SI questionnaire, adopted from Chen et al. (1999), consists of five scales: *novelty*, *challenge*, *attention demand*, *instant enjoyment*, and *exploration intention*. Participants responded on a Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Sample items of the scales include "This learning activity is new to me." (*novelty*); "It is hard for me to do this learning activity." (*challenge*); "I was focused while doing this learning activity." (*attention demand*); "This learning activity is exciting." (*instant enjoyment*); "I like to find out more about how to do this learning activity." (*exploration intention*).

The engagement questionnaire, adopted from Wang et al. (2016), comprises three scales: *cognitive engagement*, *emotional engagement*, and *behavioral engagement*. Participants responded on a Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Sample items of the scales include: "I think about different ways to solve a problem." (*cognitive*); "I feel good when I am doing this learning activity." (*emotional*); "I keep trying even if the learning activity is hard." (*behavioral*).

2.3.2 Science Achievement test

We designed multiple-choice assessments to evaluate students' understanding of evaporation and condensation. The pre-test and post-test are identical and include 15 items.

2.4 Data analysis

Data will be analyzed through partial least squares structural equation modeling (PLS-SEM). PLS-SEM is considered the second generation of multivariate analysis for verifying a relationship between variables (Fornell & Larcker, 1981). Analyses will be conducted with SmartPLS version 3.3. PLS-SEM is suitable for analyzing small datasets with sample sizes and does not require normal data distribution (Hair et al., 2021). The procedure of PLS-SEM entails assessing the reliability and validity of the measurement model's constructs and then assessing the path coefficients of direct and indirect effects between constructs of the structural model.

3. Expected results

This study proposes a research model to investigate structural relationships between EC, SI, learning engagement, and achievement in students. First, the results may establish the importance of I-type EC, as most studies have indicated a stronger influence of I-type EC compared to that of D-type EC (Cheng, 2020; Huck et al., 2020). Our results may also determine the importance of *novelty*, *instant enjoyment*, and especially *exploration intention*, in GBL environments, as prior research has indicated the benefits of learning in virtual environments for SI (Chen et al., 2016; Lin et al., 2021). Finally, we intend to compare our results with those obtained by Cheng et al. (2022), who proposed a similar research model that found EC to positively correlate with SI, attitudinal learning, and the mediation of SI.

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