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RESEARCH ARTICLE

Relationships between students' affective experiences and technology acceptance in augmented reality design training in higher education

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Abstract
Although numerous studies have demonstrated the potential benefits of augmented reality (AR) in education, the influence of education students' learning experiences on their AR technology acceptance in the classroom has yet to be examined thoroughly. In this empirical study, we explored the affective experiences (i.e., positive emotions, negative emotions, and situational interest) of education students in AR training and examined how their affective experiences influence their AR technology acceptance (i.e., perceived ease of AR use, perceived usefulness of AR, and intention to use AR) by using the partial least squares path modeling method. Our results show that situational interest significantly predicts both the perceived ease of AR use and the perceived usefulness of AR. Moreover, positive emotions significantly predict the perceived ease of AR use. However, negative emotions were not noted as a factor influencing either the perceived ease of AR use or its perceived usefulness. These findings indicate the importance of promoting situational interest and positive emotions in AR training to increase AR technology acceptance among education students in the classroom setting.

Keywords Augmented reality · Positive emotion · Negative emotion · Situational interest · Technology acceptance

Introduction

For the past decade, augmented reality (AR) has gained popularity as a promising technology offering unique learning experiences in educational settings (Johnson et al., 2010; Pathania et al., 2023). AR systems allow real and virtual objects to coexist in the same space and

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interact with each other in real-time (Azuma, 1997). Combining virtual digital data with a real-world environment provides users with access to rich and meaningful multimedia content that is contextually relevant and leads to immediate actions (Billinghurst et al., 2001). This ability to overlay media onto real-world objects enables learning through various methods and provides the type of scaffolding many students require to reduce their cognitive overload (Bower et al., 2014).

However, although many AR research findings have indicated the potential benefits of this technology in various subject areas (see Bacca et al., 2014), AR has yet to be widely adopted in the classroom. Research has identified several barriers herein, including time constraints with training, low knowledge/skills on AR technology, and the affordability of AR devices (Bower et al., 2014; Lee, 2012). Moreover, psychological barriers, such as resistance to change and minimal intentions to use AR, have also been reported as key barriers (Alkhattabi, 2017). Students' affective learning experiences, whether positive or negative, influence their motivation to engage with newer technologies (Bujak et al., 2013), as well as their beliefs and decision-making (Gratch & Marsella, 2004). Hence, to ensure the successful implementation of this technology in the classroom setting, AR learning/training programs must be designed that aim to help education students gain sufficient knowledge and skills in this area, thereby promoting and maximizing their positive affective experiences, such as those surrounding their intentions to use AR in the classroom.

Technology training involves various forms of instructional methods, such as lectures, discussions, or hands-on activities. Among these methods, hands-on design activities have been the most widely adopted instructional method in technology training for education students because, according to the constructionist learning perspective, learning through design activities is effective in providing meaningful and motivating experiences by engaging students in the process of constructing digital artifacts (Kafai, 2006). Direct involvement in the AR design process can aid students in building their AR skills and continuously reconstructing their gained knowledge through personal design experiences (Lee & Kolodner, 2011; Papert, 1993), thereby leading to higher levels of engagement (Bower et al., 2014). However, designing an educational intervention using modern technology, such as AR, involves numerous trials and errors, with it often necessitating continuous yet challenging decision-making processes during the design process. This complexity in design tasks can lead to increased student efforts that may cause them to react negatively to AR (Keller & Block, 1997; Peracchio & Meyers-Levy, 1997). Therefore, the affective experiences that students undergo resulting from AR technology training are crucial for understanding their perceived intentions to use this technology in the classroom; this is important because successful AR technology integration cannot be achieved if education students do not accept it.

In this study, we aimed to explore the affective experiences (i.e., positive emotions, negative emotions, and situational interest) of education students when they are engaged in AR hands-on design training. In addition, we examined whether their affective experiences during AR training further influence their perception/acceptance of AR technology. Our study findings provide guidance on the design of AR training activities for education students to improve their overall cognitive/affective learning experiences and their use of AR technology in the classroom.

Literature review

AR design training with hands-on activities

AR training offers an opportunity for education students to be engaged in the design of AR learning materials that enable the visualization of digital instructional content on a mobile device. By adopting a learning-by-designing approach with hands-on activities, education students undergoing AR technology training are able to learn about the design process of AR artifacts as they can be integrated into the classroom, as well as the concepts and cases of AR implementation in classrooms. This training is also expected to alter student attitudes toward AR technologies and their intentions around increasing their employment of it. Through AR design activities, students can explore the unique features of AR technology and understand the benefits of integrating it within the learning process.

The integration of hands-on activities in technology instruction programs is supported by constructionist learning. According to Papert and Harel (1991), the constructionist approach perceives learning as a construction of knowledge through the creation of artifacts. Constructionist theory also extends the scope of learning to be increasingly meaningful and motivational, wherein learners gain knowledge by designing projects or digital artifacts (Kafai, 2006). Learners are placed at the center of the design process, which involves a continuous inquiry and reasoning process. Eventually, learners construct new knowledge by planning and designing activities in an authentic learning setting (Gómez Puente et al., 2013). Many studies have indicated that the learning-by-design approach is an effective instructional strategy for educators' technology training. For example, Koehler and Mishra (2005a, 2005b) stated that technology training for teachers needs to include hands-on design activities involving technological artifacts because it helps them to develop their technological, pedagogical, and content knowledge. Recently, Ke and Hsu (2015) found that mobile AR design activities for collaborative learning provide a stronger promotion for the development of technological pedagogical content knowledge, compared with AR viewing-only activities.

The hands-on design approach also offers a key instructional strategy for increasing student engagement (Ristimaki et al., 2006). For example, students are authentically engaged when class activities involve product focus (i.e., a lesson connected to a product), choice (i.e., students are given a choice of presentation mode and, sometimes, topic), affiliation (i.e., being allowed to work with others), affirmation (i.e., letting others see their work), authenticity (i.e., when work is real and meaningful), and novelty and variety (i.e., using technology through significant methods). These diverse aspects of hands-on activities should be considered when designing technology-assisted class activities (Brown & Warschauer, 2006), thus enabling more permanent and meaningful learning to occur that then increases student achievement and motivation (Ullah & Wilson, 2007).

Due to the nature of the learning-by-designing environment, students are expected to present highly positive affective experiences when engaged in hands-on design activities with AR technology. In particular, design as a learning process supports the notion of constructionist learning, which involves providing the learner with a choice regarding the design aspect to focus on while creating an AR artifact. By adopting the learner-centered approach, AR creation activities allow students to scaffold and construct new knowledge by utilizing their individual experiences and prior knowledge (Willett, 2005).

In this study, we argue that education students' affective experiences during AR training play a key role in influencing their perceptions of AR technology and can enhance their intentions around using it. However, few studies have examined the affective experiences of education students during AR training with hands-on activities despite the fact that engagement has been identified as one of the benefits of hands-on activities. In particular, students' emotional experiences (Kim, 2012; Pekrun, 2006; Wijekumar, 2021) and their perceived interest (Renninger & Hidi, 2011) as triggered by AR design activities have yet to be empirically explored in the literature. Recently, Ke and Hsu (2015) compared AR design activities with a traditional instructional method; however, students' affective experiences were not considered in their study, despite emotion and interest serving as essential factors in encouraging technology acceptance. Park and Braud (2017) compared the hands-on design activities of students using multimedia tools on their motivation; however, the emotions and interests of the participating students were not examined.

Affective experiences in technology training

Affective experiences in a given learning environment generally refer to learners' emotional state or mood (Ahn & Shin, 2015; Jarrell et al., 2017), which is often an outcome of a student's subject appraisals of the learning tasks that they undertake (Pekrun & Perry, 2014). Unlike mood, which does not necessitate any explicit referents (Bagozzi et al., 1999), emotions develop based on appraisals of an important and relevant event to a given person (Cohen et al., 2012). In technology training settings, emotions are known to influence the cognitive processes and behavioral inclinations of trainees, with them then predicting training outcomes as well as students' perceived values and preferences (Ahn & Shin, 2015; Harley et al., 2016; Pekrun & Perry, 2014). In particular, positive and negative emotions, which are two types of well-accepted affective experiences, have been noted as critical components in the valuation process of technology training events (Barrett et al., 2007; Clore & Huntsinger, 2007). For example, positive emotions, such as enjoyment, hope, and pride, encourage students to take part in technology and learning events, whereas negative emotions, such as anxiety, anger, and shame, often result in students avoiding these events (Ahn & Shin, 2015).

The positive and negative emotions in this study were based on the types as considered in Pekrun's (2006) achievement emotion classification and Beaudry and Pinsonneault's (2010) emotion classification framework. Pekrun's (2006) achievement emotions categorize positive and negative emotions into three areas of learning: activity emotions, prospective outcome emotions, and retrospective outcome emotions. Among these three types, activity and retrospective outcome emotions are particularly crucial in this study because the former are related with students' appraisals during their AR training activities, with the latter focusing on the type of emotion experienced after the AR training activities are completed. Furthermore, Beaudry and Pinsonneault's (2010) emotion classification framework explains that emotional reactions to new information technology-induced changes are determined by two appraisals: primary (i.e., appraisals of the anticipated outcomes of an information technology stimulus event) and secondary appraisals (i.e., appraisals of the student's control over the event). These two appraisals then involve four classes of emotions, including loss, deterrence, challenge, and achievement, as presented in Table 1.

Another aspect of affective experiences in technology training is situational interest. According to Ainley (2006), "the feeling of interest involves positive activation (affect), directed attention and impulses to action" (pp. 398–399).

As an affective experience, interest initiates one's motivation to explore new events and develop diverse experiences (Izard & Ackerman, 2000; Keller, 2010; Loewenstein, 1994;

Table 1 Emotion classification framework

	During activity emotions	Retrospective outcome emotions
Positive emotion	Enjoyment (achievement emotion) Excitement (challenge emotion)	Pride
Negative emotion	Frustration (loss emotion) Anxiety (deterrence emotion)	Shame

Silvia, 2006). Situational interest occurs in response to the external environment or a given situation (Hidi & Anderson, 1992; Hidi & Baird, 1986; Hidi & Renninger, 2006; Krapp, 2002) and is triggered by the instructional environment at the initial stage of interest development (Hidi & Renninger, 2006; Krapp, 2002). Although interest is often associated with positive affect, emotion and interest have different antecedents (Reeve, 1989). For example, situational interest results from the triggering feature of a task itself, whereas positive emotions result from experiencing satisfactory performance of the task (Reeve, 1989). Hence, a student's situational interest in participating in AR design activities is orthogonal to whether they experience positive emotions, such as joy, from the experience itself. Frijda (1986) also insisted that emotions primarily modulate courses of action, but that interest in a particular action can exist before the action is taken.

The inclusion of situational interest in the examined affective experience in this study is crucial because AR is a relatively new technology among education students, meaning that they had no previous instruction or learning experiences with using this technology in the classroom or in designing AR artifacts. Emotions are cognitive representations of appraisal-driven responses to the overall lesson. Situational interest is increasingly specific to a particular situation, such as AR design activities. Hence, students' perceived situational interest while completing each set of training activities must be considered separately from the two aforementioned types of emotions. On the other hand, research has suggested that instructors develop hands-on learning activities, such as game-based learning, problem-based learning, group learning, and simulations for stimulating situational interest in learners (Hunsu et al., 2017). Many researchers have posited that situational interest has considerable potential for enhancing students' intrinsic motivation, attitudes toward learning, and positive learner behaviors that are associated with student achievement (Hunsu et al., 2017; Palmer, 2004; Renniger & Hidi, 2011).

Affective experience and technology acceptance

User perceptions and acceptance of new technology are often challenges because educational institutions lack information about the constructs that are critical for initiating technology integration in instructional practices for learning (Scherer et al., 2019). Among the literature, the primary focus has been on examining how ongoing technology integration in the classroom leads to affective learning experiences that subsequently influence learners' cognitive functions, including their beliefs, attitudes, and motivation (Beaudry & Pinsonneault, 2005, 2010). Empirical research has shown that affective learning experiences are associated with learning performance (Harley et al., 2016; Pekrun & Perry, 2014) and both intrinsic and extrinsic motivation (Isen & Reeve, 2005). For example, positive emotions, such as enjoyment, are typically connected to adaptive learning performance, with negative emotions, such as boredom, being negatively associated with intrinsic motivation, self-regulation, effort, and performance (Harley et al., 2016; Pekrun et al., 2014). Furthermore, positive affect plays a key role in increasing the positive evaluation of enjoyable learning situations that promote learners' conducive behaviors, such as self-control, problem-solving, and decision-making (Isen & Reeve, 2005). Because different emotions are associated with cognitive and motivational functions in the positive valence of specific decision-making processes, such as new technology acceptance, understanding user intention to utilize new technology is a multifaceted and complex issue.

Davis et al. (1989) proposed the Technology Acceptance Model (TAM) to describe the acceptance and use of novel technology (Davis, 1989). TAM suggested that behavior intention (BI) can be explained by three cognitive and psychological constructs: perceived ease of use (PEU), perceived usefulness (PUS), and attitude towards using technology (ATUT) (Granić & Marangunić, 2019). Individual's BI is a major determinant of new technology adoption and use (Al-Adwan et al., 2023), whereas ATUT is a core predictor of BI, which determines whether the individual will accept or reject the new technology (Granić & Marangunić, 2019). ATUT can be jointly determined by PUS and PEU (Al-Adwan et al., 2023). Thereafter, Davis (1989) hypothesized external constructs that directly influence the three essential constructs to determine BI of the new technology. Thus, the original TAM allows numerous researchers to investigate the extent to which external factors influence the core constructs of TAM (Rafique et al., 2020).

According to TAM (Davis et al., 1989), PEU is defined as the degree to which an individual believes that using a particular system will be free of physical and mental effort. PUS is defined as the degree to which an individual believes that using a particular system will enhance their job performance. PEU is also a determinant of PUS because students would consider a system useful when it is easy to use without requiring much effort (Yi & Hwang, 2003). The two major constructs influence an individual's BI to use a new system, hence BI to use is defined as the determination of whether the individual will use the system or not (Davis, 1989). Accordingly, this study extended TAM by incorporating several affective external constructs that have not yet been addressed.

Within the current emphasis on AR technology acceptance and integration into education curricula in higher education (Balog & Pribeanu, 2010; Ibili et al., 2019), TAM in this study is considered a comprehensive theoretical framework for investigating how students' affective experiences influence their perceptions toward adopting new AR technology and how they use it in learning activities. Scherer et al. (2019) noted that TAM was crucial for explaining user intentions and actual technology use behaviors in various educational contexts, such as different self-directed learning levels (Gokcearslan, 2017), those involving education students of different cultural differences (Teo et al., 2008), and among pre- and in-service teachers (Teo, 2015). Furthermore, Yang and Wang (2019) posited that external constructs in the extended TAM play a crucial role in providing an improved understanding of new technology acceptance and user behaviors in the literature.

Few studies have focused on how affective learning experiences predict user perception/acceptance of new technology and their initial use of it (Beaudry & Pinsonneault, 2010). Venkatesh (2000) noted the influence of emotions as an anchor that determines early perceptions about the ease of use of a new technology system, such as computer self-efficacy and anxiety. On the other hand, in terms of increasing experience with a specific target technology over time, perceived enjoyment (which is regarded as one of the key adjustment factors) has been identified as significantly influencing users' intentions to use new technologies (Venkatesh, 2000).

Davis et al. (1989) noted that perceived enjoyment is a form of intrinsic motivation that enables learners to experience pleasure and satisfaction following a specific activity. Perceived enjoyment was found to be a significant predictor of user intention to use new technology, including AR technology (Balog & Pribeanu, 2010). Likewise, perceived enjoyment was found to impact peoples' perceived usefulness, perceived ease of use, and intention to use technology (Lee et al., 2019; Teo & Noyes, 2011). Regarding negative affects, computer anxiety has been recognized as a crucial construct related to the acceptance of new technology in computer-supported educational environments throughout the extant literature (Celik & Yesilyurt, 2013). Studies have also confirmed that mobile device and ICT anxiety play a key role in adopting mobile technologies for learning (Mac Callum & Jeffrey, 2014; Nikou & Economides, 2017). Learners with higher levels of anxiety perceive new technologies as being more difficult to use, thereby negatively impacting their behavioral intentions to use them.

However, few studies have focused on the extent to which students' affective experiences determine their perceptions of AR technology acceptance while participating in hands-on training. Unlike other technology training that generally focuses on how to use a type of technology, AR hands-on training provides a unique opportunity to gain AR design skills for interactive and immersive learning materials. Hence, a set of characteristics should be considered in AR training. For example, AR training phases need to be tightly bridged (Sadagic et al., 2019) to logically flow from concept learning to design skill acquisition using an AR design tool. Since the focus of the training is not on how to use AR but on how to design AR materials, the training activities need to be closely intertwined to maximize the outcome of the hands-on activities.

Students also need to be given the opportunity to review and analyze the best practices of well-designed AR materials for learning. Prior to being engaged in hands-on AR design activities, well-implemented design principles in real AR learning products should be examined so that students can understand and apply the design principles to their own AR design activities. In addition, the success of AR training experiences depends on how a selected AR design tool could support the intended learning goals in the AR materials. It is important to use an AR design tool that offers an easy-to-follow design interface, interactive modalities, and potential system compatibility (Sadagic et al., 2019). As discussed in the previous section, participating in such AR design training involves significant efforts with trial and error, hence students often experience various types of emotions during the design process.

Therefore, in this study, we aimed to examine education students' affective experiences (i.e., positive emotions, negative emotions, and situational interest) in AR training and develop a comprehensive understanding of how these affective experiences affect their acceptance of AR technologies based on the TAM (Davis et al., 1989; Teo & Noyes., 2011).

Research questions and model

In this study, we addressed the following research questions:

RQ1 How do education students perceive their own affective experiences (i.e., positive emotions, negative emotions, and situational interest) and acceptance of AR technology while participating in AR training?

Table 2 Hypotheses to be tested

Hypothesis	Supporting references
H1: positive emotion (PEM) is positively related to perceived ease of AR use (PEU).	Lee et al., (2019); Teo & Noyes, (2011)
H2: positive emotion (PEM) is positively related to perceived usefulness of AR (PUS).	Lee et al., (2019); Teo & Noyes, (2011)
H3: negative emotion (NEM) is negatively related to perceived ease of AR use (PEU).	Mac Callum & Jeffrey, (2014); Nikou & Economides, (2017)
H4: negative emotion (NEM) is negatively related to perceived usefulness of AR (PUS).	Mac Callum & Jeffrey, (2014)
H5: situational interest (SIT) is positively related to perceived ease of AR use (PEU).	Hunsu et al., (2017); Yang & Wang, (2019)
H6: situational interest (SIT) is positively related to perceived usefulness of AR (PUS).	Hunsu et al., (2017); Yang & Wang, (2019)
H7: perceived ease of use (PEU) is positively related to perceived usefulness (PUS).	Davis et al., (1989)
H8: perceived ease of use (PEU) is positively related to intention to use AR (ITU).	Davis et al., (1989)
H9: perceived usefulness (PUS) is positively related to intention to use AR (ITU).	Davis et al., (1989)

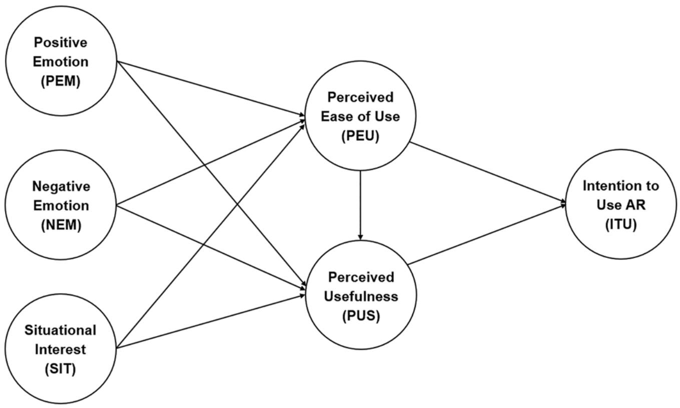

Fig. 1 Research model

RQ2 What are the relationships between education students' affective experiences and their acceptance of AR technology?

Specifically, the following link specifications between the three types of affective experiences and TAM factors (i.e., perceived usefulness, perceived ease of use, and intentions to use AR) were established to present the hypothesized relationships in RQ2 (see Table 2). Figure 1 illustrates the research model developed in this study.

Methods

Participants

A total of 98 undergraduate and graduate education students participated in this study and completed AR training involving AR design activities at a public four-year university in the southeastern region of the United States. The AR training was offered as part of the education courses that the students were enrolled in, which includes general introductory educational technology courses, such as Introduction to Educational Technology, and Trends and Issues in Instructional Technology, and Interactive Media. Only students who agreed to participate in the study by signing the informed consent form were included in the final data analyses. No compensation or course credits were offered. After eliminating three incomplete questionnaires, 95 responses were analyzed. The participants included 73 female students (76.8%) and 22 male students (23.2%). The average age was 27.41 years ($SD = 8.13$). In terms of ethnicity, the study included 57 Caucasian students (60.0%), 17 Asian and Pacific Islander students (17.9%), 11 African American students (11.6%), and 10 Hispanic students (10.5%). There were 10 freshmen (10.5%), 21 sophomores (22.1%), 10 juniors (10.5%), three seniors (3.2%), and 51 graduate students (53.7%).

AR design training

The overall goal of the AR training program was to promote awareness and understanding of AR technology in education among education students. Prior to completing the questionnaire, participants completed the AR training, which consisted of the following three activities: (1) AR presentation: An instructor delivered a 20-min introductory presentation on AR, (2) AR case analysis: Each student searched for two cases of AR implementation in education and analyzed them based on pre-determined criteria, and (3) AR design activities: Each student designed an AR learning experience using a mobile AR creation tool.

The AR case analysis activities were designed to facilitate students' active discussions through AR case searches on the Internet, case reviews, case analyses, and case discussions. For example, students used the Google search engine to find two cases of AR design/use in education and analyzed each one based on the following aspects: target audience, subject area, objectives of AR experience, design, development, AR experience, and potential modifications.

In the AR design activities, the participating students designed an individual AR learning experience, following the tutorials, using a mobile AR creation tool that offers both a mobile app and a computer-based design studio program for educational purposes. It has been reported as a good design application for beginner students who do not have computer programming skills (see Ke & Hsu, 2015). Students followed the technology artifact design process with the following seven steps (Han & Bhattacharya, 2001): (1) select a topic or task, (2) describe the audience, (3) create the artifact, (4) pilot the artifact, (5) receive feedback, (6) reflect on the artifact and feedback, and (7) redesign the artifact. Through this design process, students can activate, expand, modify, externalize, revise, and recreate content knowledge while becoming familiar with the technology tool (Han & Bhattacharya, 2001).

Instruments

A self-report questionnaire was administered through the Surveymonkey online survey system. In the first section of the survey, we measured students' demographic information, such as their gender, age, grade level, and ethnicity. To measure affective experiences in three sub-constructs, we adopted the instrument items from the previously validated achievement emotions questionnaire (Pekrun et al., 2011), the discrete emotions questionnaire (Harmon-Jones et al., 2016), and the situational interest survey (Chen et al., 2001) and revised the wording to reflect the AR training context.

The affective experience was defined as learners' positive or negative emotional states as an outcome of subject appraisals of learning tasks in a learning environment (Pekrun & Perry., 2014). Thus, affective experiences occur during the learning process while participating and completing learning tasks. Positive emotions and negative emotions are two components of affective experience that play a crucial role in determining the value of technology training (Barrett et al., 2007). As discussed in the literature review, positive emotions such as enjoyment, hope, and pride actively engage students in technology and learning events, whereas negative emotions such as anxiety, anger, and shame inform students to avoid technology and learning events (Ahn & Shin, 2015). Hence, students' affective states significantly influence their perceptions of technology characteristics and willingness to learn and use the technology (Ahn & Shin, 2015). Situational interest is defined as an immediate affective response to particular stimuli, objects, or learning conditions by the presence of interest-inducing factors (Park, 2016; Plass & Kaplan, 2016; Renninger & Hidi, 2011). Interest, as an affective experience, motivates students to explore new ideas and opportunities and further encourages them to use and adopt new technologies (Ahn & Shin, 2015).

Students' perceived technology acceptance was measured using the TAM (Davis, 1989; Teo, 2009) consisting of three constructs that are perceived ease of use, perceived usefulness, and intention to use. All items used a seven-point Likert scale, ranging from 1 = *strongly disagree* to 7 = *strongly agree*. The survey items and reliability are presented in Table 3.

Data analysis

Prior to the primary data analysis, we compared the affective experiences of students and their perceived AR technology acceptance by sex and ethnicity to confirm that both of these factors would not affect our outcome variables. For the main analysis, a partial least squares (PLS) path modeling method was utilized using SmartPLS software (Ringle et al., 2015). PLS modeling was selected because it aims to assess the extent to which a part of the research model predicts values in other parts of the research model (Fornell & Larcker, 1981). We followed both the rule of thumb guidelines suggested by Hair et al. (2011) and the guidelines for evaluating and using PLS provided by Peng and Lai (2012). The sample size, 95, was deemed adequate based on the sample size consideration for PLS because PLS requires a minimum sample size that is ten times the largest number of structural paths in the structural model.

According to Hair et al. (2011), The measurement model was first analyzed to test its psychometric properties, with the structural model for path testing being presented in the next section.

Table 3 Affective experience and AR technology acceptance items and internal consistency coefficient

Measure	Constructs (Number of items)	Items	Internal consistency coefficient
Affective experiences	Positive emotions (3)	PEM1: I enjoyed the augmented reality training. PEM2: The augmented reality training was exciting. PEM3: I am proud of my accomplishment in the augmented reality training.	.81
	Negative emotions (4)	NEM1: I feel frustrated during the augmented reality training. NEM2: I got tense and nervous during the augmented reality training. NEM3: I felt ashamed during the augmented reality training that I couldn't absorb the simplest of details. NEM4: The augmented reality training was irritating.	.85
	Situational interest (3)	SIT1: The augmented reality training activities were interesting. SIT2: The augmented reality training activities looked fun to me. SIT3: It was fun for me to try the different augmented reality training activities.	.81
AR technology acceptance	Perceived ease of AR (5)	PEU1: My experience with augmented reality was clear and understandable. PEU2: I find it easy to get augmented reality to do what I want it to do. PEU3: I find augmented reality easy to use. PEU4: Learning to use augmented reality is easy for me. PEU5: It is easy for me to become skillful at using augmented reality.	.95
	Perceived usefulness of AR (3)	PUS1: augmented reality technology will improve my work. PUS2: Using augmented reality technology will enhance my effectiveness. PUS3: Using augmented reality technology will increase my productivity.	.96
	Intention to use AR (3)	ITU1: I plan to use augmented reality technologies in the future. ITU2: I plan to use augmented reality technologies often. ITU3: I intend to continue to use augmented reality technologies in the future.	.94

Results

RQ1. How do education students perceive their affective experiences (i.e. positive emotions, negative emotions, and situational interest) and AR technology acceptance while participating in AR training?

According to the technology acceptance model (Davis, 1989), perceived ease of use, perceived usefulness, and the intention to use are three components that affect a user's usage behavior. Prior to examining the influences of affective experiences on each of the technology acceptance components, students' overall perception of their affective experiences and AR technology acceptance were compiled with descriptive analysis and intercorrelations between the variables (Table 4).

To ensure students affective experiences and their perceived AR technology acceptance were not different by gender and ethnicity, a series of an independent samples *t*-test and one-way analysis of variance (ANOVA) was conducted. There were no outliers in the data, as assessed by inspection of a boxplot for values greater than 3.0 box-lengths from the edge of the box. MRS scores for each flipped learning classroom were normally distributed, as assessed by Shapiro–Wilk's test ($p > .05$), and there was homogeneity of variances, as assessed by Levene's test for equality of variances. The results showed no significant differences between female and male students in their affective experiences and AR technology acceptance. In addition, ANOVA showed no significant differences among the ethnic groups of the students (Table 5).

RQ2. What are the relationships between education students' affective experiences and their AR technology acceptance?

Measurement model

Following Peng and Lai (2012)'s guidelines, the adequacy of the measurement model was assessed for both construct reliability and validity of the constructs in the research model.

In PLS-SEM, the purpose of the measurement model analysis is to confirm the reliability and validity of all the indicator and composite variables. Thus, a measurement model

Table 4 Means, standard deviations and person product correlations for affective outcomes and technology acceptance variables

	Variable	M	SD	1	2	3	4	5	6
1	Positive emotion[a]	5.68	1.12	–					
2	Negative emotion[a]	2.03	1.25	– 0.44**	–				
3	Situational interest[a]	6.79	0.40	0.30**	– 0.52**	–			
4	Perceived ease of AR use[b]	4.85	1.47	0.45**	– 0.48**	0.48**	–		
5	Perceived usefulness of AR[b]	4.94	1.51	0.34**	– 0.26*	0.45**	0.58**	–	
6	Intention to use AR[b]	5.20	1.47	041**	– 0.31**	0.42**	0.63**	0.78**	–

*$p < .05$; **$p < .01$

[a]Possible range for positive/negative emotions (1–7)

[b]Possible range for situational interest and technology acceptance variables (1–7)

Table 5 Mean scores of the outcome variables (standard deviation in parenthesis)

Measures[a]	Gender ($n=95$)		Ethnicity ($n=95$)			
	Female ($n=73$)	Male ($n=22$)	African American ($n=11$)	Asian ($n=17$)	Caucasian ($n=57$)	Hispanic ($n=10$)
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
PEM	5.74 (1.08)	5.50 (1.25)	5.76 (0.18)	5.24 (0.40)	5.79 (0.13)	5.73 (0.31)
NEM	1.97 (1.22)	2.23 (1.36)	2.32 (0.43)	2.24 (0.29)	1.97 (0.17)	1.65 (0.31)
SIT	6.79 (0.40)	6.77 (0.42)	6.82 (0.09)	6.73 (0.12)	6.80 (0.06)	6.83 (0.09)
PEU	4.90 (1.53)	4.71 (1.29)	4.78 (0.34)	4.33 (0.29)	5.00 (0.21)	5.00 (0.50)
PUS	5.05 (1.49)	4.58 (1.55)	4.36 (0.53)	4.98 (0.32)	5.03 (0.19)	5.03 (0.68)
ITU	5.29 (1.45)	4.91 (1.52)	5.39 (0.44)	4.71 (0.36)	5.30 (0.18)	5.30 (0.59)

[a]Possible range for all outcome measures (1–7)

analysis starts with the indicator loading variable analysis and finishes with the composite variable analysis. All factor loadings were higher than the suggested cut-off value of 0.70 as shown in Table 5 (Chin, 1998). The composite reliability and Cronbach's Alpha values (see Table 6) indicated good internal consistency with the threshold that is higher than the recommended 0.70 (Churchill, 1979; Gefen et al., 2000), ranging from 0.886 to 0.973 and

Table 6 Factor loadings, internal consistency reliability, and convergent validity

Construct	Items	Factor loadings	Cronbach's alpha	rho A	Composite reliability	Average variance extracted
Positive emotion	PEM1	0.831	0.808	0.825	0.886	0.721
	PEM2	0.879				
	PEM3	0.838				
Negative emotion	NEM1	0.759	0.850	0.861	0.899	0.690
	NEM2	0,843				
	NEM3	0.858				
	NEM4	0.859				
Situational interest	SIT1	0.759	0.805	0.820	0.886	0.723
	SIT2	0.927				
	SIT3	0.855				
Perceived ease of AR use	PEU1	0.817	0.946	0.953	0.959	0.824
	PEU2	0.921				
	PEU3	0.916				
	PEU4	0.925				
	PEU5	0.955				
Perceived usefulness of AR	PUS1	0.940	0.958	0.958	0.973	0.924
	PUS2	0.980				
	PUS3	0.962				
Intention to use AR	ITU1	0.941	0.944	0.945	0.964	0.900
	ITU2	0.943				
	ITU3	0.962				

Table 7 Discriminant validity check (Bold values are the square root of the AVEs)

	PEM	NEM	SIT	PEU	PUS	ITU
PEM	**0.849**	− 0.436	0.295	0.459	0.350	0.415
NEM	− 0.436	**0.831**	− 0.514	− 0.491	− 0.263	− 0.310
SIT	0.295	− 0.514	**0.850**	0.504	0.452	0.423
PEU	0.459	− 0.491	0.504	**0.908**	0.598	0.648
PUS	0.350	− 0.263	0.452	0.598	**0.961**	0.777
ITU	0.415	− 0.310	0.423	0.648	0.777	**0.949**

Table 8 Assessment for predictive relevance using the Stone–Geisser's Q^2

Construct	SSO	SSE	Q^2 (= 1-SSE/SSO)
PEM	285.000	285.000	–
NEM	380.000	380.000	–
SIT	285.000	285.000	–
PEU	475.000	339.066	0.286
PUS	285.000	187.655	0.342
ITU	285.000	126.484	0.556

0.805 to 0.958, respectively. The average variance extracted (AVE) also exceeded the recommended threshold of 0.5, ranging from 0.690 to 0.924 (Fornell & Larcker, 1981).

Discriminant validity was assessed using the Fornell-Larcker criterion (Fornell & Larcker, 1981). Table 7 presents the square root of the AVEs in bold highlighted. All the diagonal values are higher than the off-diagonal numbers, hence an acceptable degree of discriminant validity was met.

In addition, using Henseler et al. (2015)'s suggested new criterion, the heterotrait monotrait ratio of correlations (HTMT) were also checked. Since none of the HTMT confidence intervals contains 1, discriminant validity was established. According to Henseler et al. (2014), the standardized root mean square residual (SRMR) can be used as a fit measure for PLS-SEM, with a value less than 0.1 indicating a good fit. The fit indicators for the model were acceptable with 0.070 for the saturated model and 0.071 for the estimated model. Therefore, the data fit the measurement model.

Structural model

Confirming the measurement model met the suggested criteria, the structural model was examined to test the study hypotheses. The purpose of the structural model is to analyze the relationships in the proposed conceptual model. The results of the PLS analysis using the research model and the bootstrapping results respectively are as follows. The structural model was used to test the hypotheses by examining the path coefficient (β), path significance (p-value), coefficient of determination values (R^2), and predictive relevance (Q^2). Each hypothesis was tested by detecting the statistical significance of associations between variables in the hypothesized direction.

Predictive relevance was assessed using Stone–Geisser's Q^2. Hair et al. (2011) suggested that when Q^2 values of endogenous constructs that are greater than zero, the exogenous constructs have predictive relevance for the endogenous construct. Table 8 presents the Q^2 values of the three endogenous constructs (PEU, PUS, and ITU) that are greater than zero, indicating that the model had acceptable predictive relevance.

The path significance analysis was conducted using a two-tailed t-test. Hair et al. (2011) suggested the following guideline for each level of significance: Critical t-values for a two-tailed test are 1.65 (significance level = 0.1), 1.96 (significance level = 0.05), and 2.58 (significance level = 0.001). The significance level in this study was set at 0.05 as it is generally accepted in education studies. The hypothesized model accounted for 65.7% of the variance in the intention to use AR, meaning that the antecedent variables helped explain 65.7% of the variance in the intention to use AR in the classroom. The findings from the PLS results in Table 9 revealed that positive emotion only influences the perceived ease of AR but not the perceived usefulness of AR. Negative emotion was not a factor influencing either the perceived ease of AR or the perceived usefulness of AR. However, situational interest was found to be a factor affecting both the perceived ease of AR use and the perceived usefulness of AR. Figure 2 displays the standardized path coefficients of the hypothesized research model.

Discussion

In this study, we investigated the extent to which students' affective learning experiences influence their perceived usefulness and perceived ease of use in order to make predictions around their behavioral intentions to use AR technology for constructing learning content and knowledge. The key findings from this study highlight the importance of students' affective learning experiences during the designing or creating of media-centric artifacts using innovative technologies, such as AR technology. This study also contributes significantly to the literature related to TAM and relevant theoretical technology acceptance frameworks for stimulating technology-supported learning environments.

First, this study indicates that a learning-by-designing approach, such as hands-on AR training, positively impacts education students' affective learning experiences. Our findings suggest that students should be engaged in authentic learning experiences involving the construction of new knowledge while participating in various problem-solving and decision-making processes in order to make creative artifacts by using interactive AR technology (Gómez Puente et al., 2013; Kafai, 2006). As a result, our study findings confirm that engagement in authentic AR design activities influences students' affective learning

Table 9 PLS results

Hypothesis	Path	Path coefficient (β)	*t*-statistic	*p-value*	Result
H1	PEM → PEU	0.275	3.533***	0.000	Supported
H2	PEM → PUS	0.117	1.276	0.202	Not supported
H3	NEM → PEU	-0.209	1.766	0.078	Not supported
H4	NEM → PUS	0.160	1.793	0.074	Not supported
H5	SIT → PEU	0.316	3.405***	0.001	Supported
H6	SIT → PUS	0.247	3.377***	0.001	Supported
H7	PEU → PUS	0.500	5.394***	0.000	Supported
H8	PEU → ITU	0.286	3.371***	0.001	Supported
H9	PUS → ITU	0.606	8.405***	0.000	Supported

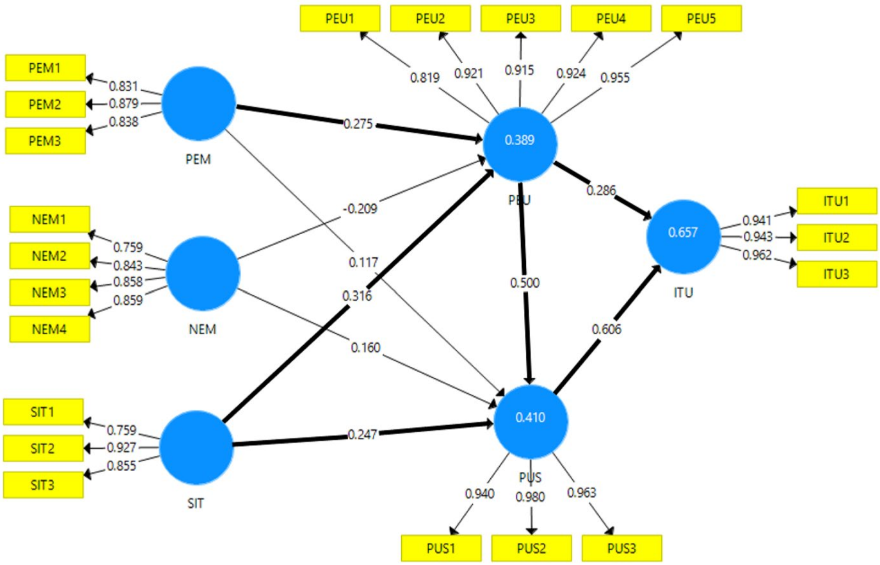

Fig. 2 Path model and PLS-SEM estimates

experiences (Ahn & Shin, 2015; Pekrun, 2006) and their overall situational interest (Renniger & Hidi, 2011). Importantly, these affective learning experiences are associated with more positive learning outcomes, such as those involved in cognitive processes (Harley et al., 2016) and learning motivation (Park & Braud, 2017). Hence, this study posits that a hands-on learning approach through AR-supported tools would enhance the positive emotions and situational interest of higher education students, which would then result in a more positive learning performance overall.

Second, we found that affective constructs, including positive emotions, negative emotions, and situational interest, provide added value to the TAM, thereby serving as the core theoretical framework for understanding education students' perceptions of using new AR technologies. In terms of the extended TAM, this study presents robust evidence that reveals that positive emotions, negative emotions, and situational interest can be used effectively as external constructs to the TAM in the context of AR technology acceptance (Scherer et al., 2019). Similarly, our findings provide a critical way of understanding the acceptance of AR technology through a constructivist learning approach among education students (Nikou & Economides, 2017). As mentioned, we developed a comprehensive model using the TAM and hypothesis testing that found that positive emotions and situational interest are significant predictors of students' intention to use AR technology in classroom activities. We also confirmed the significant influences of perceived usefulness and perceived ease of use on students' intentions to use AR applications during the learning process. Therefore, this study provides new perspectives on the extensive use of the TAM by exploring the influences of affective constructs on AR training in higher education settings.

Our study findings provide practical implications for researchers, instructors, and educational practitioners in relation to topics like emotions and immersive technology acceptance in higher education contexts. Some researchers have suggested that pre-service teachers need to develop technological, pedagogical, and content knowledge to ensure the successful integration of AR technology in learning activities (Ke & Hsu, 2015; Koehler & Misha, 2005a, 2005b). However, it is crucial for instructors and instructional designers to promote students' positive perceptions of the ease of use and usefulness in integrating AR technology, which is triggered by the positive emotions and situational interest of students while participating in hands-on learning activities. Besides, the cognitive and affective functions of immersive technology like virtual reality should be taken into account for designing learning tasks because the adoption of novel technology depends on the types of given tasks using technology characteristics (Yoon et al., 2023). Consequently, we focused on how to design and develop interesting and enjoyable learning tasks by integrating immersive technologies based on the constructivist learning process that states that promoting a positive affect increases an individual's interest and enjoyment of learning situations as well as their overall motivation and engagement (Aslan et al., 2018; Isen & Reeve, 2005).

This study addresses that technology positively influences students' perceptions when technology is effectively utilized for instructional design (Howard & Rose, 2019). Based on the beneficial influence of positive emotions and situational interest derived from hands-on learning activities, the learning by design (LBD) approach is a suitable alternative with which to provide scaffolding, thereby instituting the knowledge and skills that students can identify with during design activities (Lee & Kolodner, 2011). Schank et al. (1993) and Kolodner (1994) suggested that LBD is a feasible approach with goal-based scenario curricula wherein learning through hands-on design experiences occur by repeatedly practicing skills and using core knowledge, while also supporting students to achieve their learning goals. On this basis, LBD focuses on helping students engage in hands-on design activities, thereby providing positive learning experiences for sharing ideas, engaging in constructive reasoning with peers, and crafting artifacts on their own. Lee and Kolodner (2011) posit that LBD aids an instructor in managing classroom activities and facilitating discourse and reflection by providing structured and self-regulated learning environments. Consequently, technology-supported learning activities developed through the LBD approach would provide positively affective experiences by motivating students and engaging them in evaluating their learning goals, constructively sharing ideas, undergoing individual reasoning, making creative artifacts, and productively reflecting on the learning process.

Our findings reveal that students' intentions around using AR technology are affected by its perceived usefulness and ease of use. According to Dousay and Trujillo (2019), multimedia learning environments have considerable potential for increasing learner interest and engagement in learning contexts by utilizing multiple modalities and multimedia applications. AR technology, as an immersive multimedia tool, will help to engage learners in an authentic learning environment that is then situated within socio-culturally meaningful contexts through practice, which would then contribute to stimulating learning outcomes (Chang et al., 2016). Among various immersive technologies, virtual reality is an artificial computer-generated modern technology in education that creates a learning environment that helps students understand complex real-life issues with a sense of enjoyment and ease of use (Gnanadurai et al., 2022). Furthermore, integrating virtual reality into team education can enhance students' perceptions of collaboration and confidence in communicating with peer students (Fernandez, 2017). Within a virtual world, students can design and test digital prototypes that can be created, modified, and improved upon without paying the massive costs that would be needed to create their physical versions. In a virtual world, teachers are more responsible for providing guidance on using immersive technologies, meaning that they must then adapt their roles to that of a coach or mentor at times

(Gnanadurai et al., 2022). Therefore, instructors must understand the benefits of immersive technologies to build an interactive learning environment that enhances learners' positive perceptions and promotes improved learning performance.

Study limitations

This study includes several limitations. First, our findings need to be further tested and validated in various other contexts and populations. Data were collected from a small number of participants using a specific target technology within a specific learning setting; thus, caution should be exercised in interpreting and generalizing the findings of this study to other settings. Although research has validated the modified TAM across various target technology settings, this study proposed a replicable TAM with different external variables and confirmed the significant relationships between its latent constructs among a specific group of subjects. Hence, future research should validate our findings in different learning settings with various technology systems. Second, regardless of evaluations related to the participants' prior knowledge and skills on AR technology, this study used cross-sectional and self-reported survey responses during a specific period wherein the participants may have already been familiar with the target technology. This may lead to methodological problems related to the self-reported measurement, which is vulnerable to common method variance. For example, the affective latent constructs (i.e., positive emotions, negative emotions, and situational interest) in the TAM proposed in this study are susceptible to being affected by the participants' prior knowledge and skills around the use of AR technology. It will be necessary to investigate and interpret user acceptance and intentions through in-depth interviews about using AR technology when prior emotional investment and interest in it may be robust. Therefore, to avoid these methodological problems, future research should capture the changes caused by user acceptance of a given technology by using the same survey measures at different time points and further in-depth interviews. Finally, regarding the external variables used in the extended TAM, future research should focus on developing an empirical TAM that includes critical latent constructs associated with constructivist learning. While participating in collaborative AR artifact design activities, future researchers should develop a new proposed model herein that investigates participants' motivational and social perspectives around hands-on learning activities, including their level of self-efficacy, motivation, collaborative self-regulation, scaffolding, and interaction, as these may predict users' acceptance of innovative technology systems.

Conclusions

In conclusion, our findings provide empirical evidence around how education students' affective learning experiences are driven by hands-on AR training, as well as how this then influences their intentions to use AR technology for classroom activities. Moreover, this study developed a comprehensive model based on the TAM to investigate the structural relationships among students' affective experiences and their perceptions toward AR technology acceptance. Specifically, we confirmed that positive emotions increase students' perceived ease of use surrounding AR technologies, even if no significant evidence was found around the influence of negative emotions on their perceptions around AR technology acceptance. Situational interest, which is an individual student's reaction to the specific AR design activity, is a significant predictor of their intentions to use immersive AR technologies in future learning tasks. Overall, students' affective experiences during AR technology-supported learning were found to be crucial determinants of their acceptance of this new technology. Regarding the extensive use of the TAM within the education context, our findings highlight the key roles of external constructs, such as positive emotions, negative emotions, and situational interest, in comprehensively understanding end-users' perceptions of AR technology. Hence, this study addresses the gap in the literature in its finding that a better understanding of students' affective learning in educational settings must be acquired through the TAM theory. Furthermore, this study presents empirically positive evidence that students' affective experiences and preferences for immersive technologies used in technology-supported learning environments are associated with their level of engagement and learning performance in hands-on learning activities.

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