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A Model for Augmented Reality Immersion Experiences of University Students Studying in Science Education

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Abstract

The aim of this study is to investigate the augmented reality (AR) immersion experiences of university students studying in science education. The relationship between interest, usability, emotional investment, focus of attention, presence and flow was examined for university students studying in the science education department who used AR technology. The research design adopted is a correlational method, an established experimental research method. The sample consisted of 180-university students studying in the science education department (32 males, 148 females) of the Faculty of Education. The data obtained were analyzed according to the structural equation model. A model was developed which is capable of explaining 71% of the variance in university students' flow experiences. According to our model, focus of attention and presence of university students have an influence on their flow experiences. The study also showed that emotional investment and presence of university students influences their focus of attention. In addition, usability and emotional investment of the students influences their interest.

Keywords Augmented reality · Science · Modeling · Undergraduate education

Introduction

In this digital era where technology shapes our thinking and learning style, it is especially important that education environments share in the benefits (Cheng et al. 2015). Therefore, science teachers need to focus not only on developing students' science understanding but also on improving the integration of learning technology in the classroom to prepare these students for their future roles in the twenty-first-century workforce (Pringle et al. 2015). Technological products such as computers, smart boards, and smartphones have been shown to have great potential for students in aiding their understanding of science (Hug et al. 2005; NRC 1996) and in integrating them successfully in the learning process (Blumenfeld et al. 2000). As access opportunities increased, more science teachers chose to use technology in their classes to teach, to consolidate the science concept, and to develop students' problem-solving skills (Guzey and Roehrig 2009; Slykhuis and Krall 2011). It was seen that performance outcomes are better when technological applications are used which enable greater student interaction in the education setting and increased motivation toward class is generated (Billinghurst 2002; Dalgarno and Lee 2010; Kye and Kim 2008; Lee et al. 2010). One of these technological applications is augmented reality (AR), as described in the New Media Consortium (Becker et al. 2017).

AR systems simultaneously integrate real and virtual worlds and include virtual objects in real-world environments (Azuma 1997; Milgram and Kishino 1994). According to Bower et al. (2014), the use of AR in education provides benefits through the acquisition of knowledge and experience that can be abstract, difficult to understand, hard to observe, and possibly hazardous in a class environment. AR can be defined as a valuable educational tool which has great potential for future learning with regard to the development of creative skills (Bower, 2014). AR has been recognized as a technology which can help students achieve real-world goals through interaction with objects from virtual environments (Chang and Hwang 2018). The literature on AR applications

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in education claims a number of educational benefits, including increasing students' motivation in the lesson (Cai et al. 2013; Ferrer-Torregrosa et al. 2015; Sumadio and Rambli 2010; Wojciechowski and Cellary 2013), presenting an effective and efficient learning environment (Iordache et al. 2012), and eliciting positive emotional responses (Huang et al. 2016). In addition, AR enables students to experience flow (Davis et al. 1989; Bressler and Bodzin 2013, 2016) and helps to create a more complete focus through an immersion experience which results from interesting activities (Cheng et al. 2015). Kye and Kim (2008) stated that AR technology could play a key role in facilitating the experience of flow and immersion. The flow and immersion experience of students while using AR is the main focus of this study.

Flow and Immersion

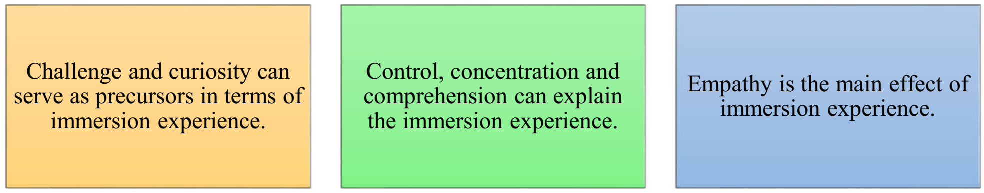
Flow is a positive psychological state that is challenging, rewarding, and enjoyable. In flow, people feel that they are involved in meaningful activities and maintain their focus on the target (Csikszentmihalyi 1997). Csikszentmihalyi (1975) stated that a flow experience "happens when a person actively interacts with the environment" and that flow is when people are intensely involved in an activity and experience a high level of motivation. This satisfactory situation challenges individuals to work willingly to dispel anxiety in pursuit of success, to achieve that success, and to work to sustain it (Cheng et al. 2015). Flow can be described as an experience that attains a balance between possessed skills and motivation to achieve (Ibañez et al. 2014). This experience is related to nine psychological attributes. These are expressed as open targets, urgent feedback, skills against challenges, integration of action, and awareness, focusing on duty, control, loss of self-consciousness, changing time perception, and ending the experience in a unique way (Csikszentmihalyi 1990). Ghani and Deshpande (1994) worked on Csikszentmihalyi's flow experience concept and determined that flow experience has two main components which they referred to as "concentration" and "entertainment." According to Ghani and Deshpande (1994), in flow experience, when entertainment accompanies absolute concentration, time perception in the course of any activity will disappear altogether. Although the intertwined structure of immersion and flow makes it difficult to distinguish between these concepts, immersion is often used with reference to the participation rate, while the flow is used to refer to inclusion and the harmony of individuals while engaged in the particular activity (Cheng et al. 2015).

The term "immersion" can be explained by flow theory, as suggested by Csikszentmihalyi (1975). Many researchers in the virtual reality field described immersion as the "purpose" of a virtual environment and "measurable" features (Bystrom et al. 1999; Nash et al. 2000; Slater 1999). Witmer and Singer (1998) and other researchers claimed that immersion "is a constant psychological state involving continuous interaction with stimuli in the environment" and they provided a technical definition which allowed this idea to be accepted as a measurable concept. Subsequently, other researchers asserted that immersion was not a new construct linked to the emergence of virtual reality technologies but it can occur with other emotionally engrossing experiences such as simple audio and visual desktop computer use or even non-technological activities such as storytelling (Brooks 2003; McMahan 2003). Therefore, immersion can naturally occur while reading a book, watching a movie, or playing a digital game as individuals interact with an attractive activity (Weibel et al. 2010). As a result, multiple approaches are applied in an attempt to measure engrossing psychological experiences. According to Brown and Cairns (2004), immersion is a psychological process which consists of three stages completed, in ascending order, as follows: engagement, engrossment, and total immersion. Stage one is *engagement,* which in turn comprises the concepts of access and investment. Access refers to game preference and game controls. *Investment* is where players become more involved with the game. *Engrossment* is the second stage where players' interests in the game and emotional attachment are determinant factors. Lastly, total immersion is the highest level of flow experience, where gamers experience a sense of belonging in the game world and often feel that the game becomes more important than everything else at that time.

Measuring Immersion

Jennett et al. (2008) developed the Immersive Experiences Questionnaire (IEQ) to measure immersion in digital games. The IEQ items were developed from Brown and Cairns' (2004) immersion model as well as flow-related concepts (Csikszentmihalyi 1990), cognitive absorption-related concepts (Agarwal and Karahanna 2000) and presence-related concepts (Witmer and Singer 1998). Items included in the survey were based on five key factors, which are considered essential in creating an engrossing experience. These are cognitive inclusion, emotional inclusion, real-world disintegration, challenge, and control (Georgiou and Kyza 2017). Related to immersion experience, Qin et al. (2009) suggested that involvement in the fictional narrative of a digital game was the reason for the immersion effect. To measure players' immersion experience in a game setting, the authors developed a Game Immersion Questionnaire (GIQ). In this questionnaire, to examine the immersion experience, a model was created using antecedents, experience and engrossment effect dimensions. Figure 1 below summarizes the immersion model developed by Qin et al. (2009).

Fig. 1 Qin et al. (2009) immersion model



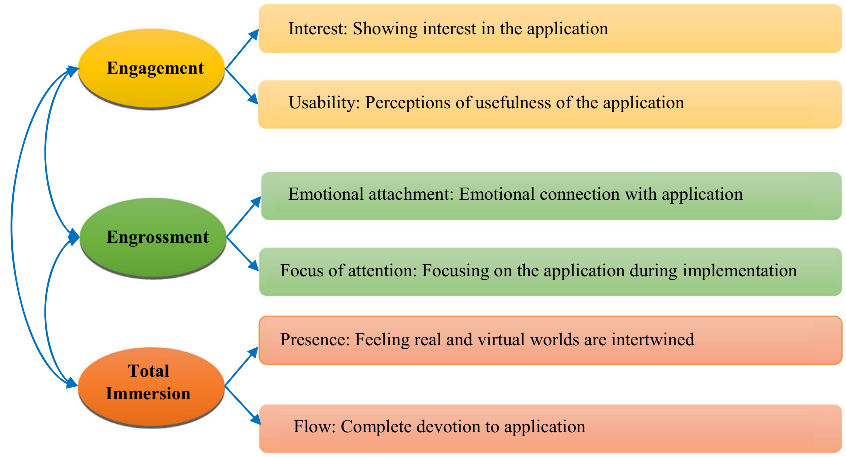
Another questionnaire in the literature is the Game Immersion Questionnaire developed by Cheng et al. (2015) to measure immersion in game-based virtual worlds. Results obtained from Brown and Cairns' (2004) settled immersion theory questionnaire showed that this questionnaire has more dimensions than their global model. A model that describes immersion in three stages was developed. These stages were expressed as "engagement," "engrossment," and "total immersion," with each stage broken down further into sub-dimensions. According to Cheng et al. (2015), *engagement* involves attraction, time investment, and usability sub-constructs, *engrossment* includes emotional attachment and reduced environmental perception, and *total immersion* is categorized by presence and empathy. Note that a common aspect of these questionnaires mentioned above is that they were designed to measure immersion in relation to digital games. Location-based AR applications are technologies which significantly differ from other digital environments (Wagner et al. 2009). Therefore, this questionnaire is not adequate as a measure of immersion in an AR environment (Georgiou and Kyza 2017). For this purpose, Georgiou and Kyza (2017) developed an ARI questionnaire and described as a graded psychological construct. This was based on cognitive and emotional participation in immersion and on the theoretical model presented by Brown and Cairns (2004), Cheng et al. (2015), and Jennett et al. (2008).

The ARI questionnaire uses the same terms for the three constructs: engagement, engrossment, and total immersion (Brown and Cairns 2004). Engagement is the first step of immersion. This is where the user has the lowest level of interest in the application. After the engagement, the engrossment stage involves drawing the users more to the application and holding their attention. Total immersion involves diversion from reality and the user becoming totally submerged in the application. Cheng et al. (2015) presented these three constructs in the form of a seven-factor scale to measure the level of game immersion. Based on this study, Georgiou and Kyza (2017) developed their ARI questionnaire, opting for six factors in their scale. Georgiou and Kyza's (2017) ARI questionnaire model is summarized in Fig. 2.

Evidence of the positive effects of these factors on learning can be seen in previous literature on AR use in education. For example, Di Serio et al. (2013) introduced AR applications to secondary educational-level students and found that students' interest and attention increased. Another study emphasized the importance of the concept of usability if users are to devote themselves to technology (Davis 1989). High emotional attachment encourages developed learning (Graetz 2006). Including mobile devices in students' learning helps them to better focus on learning (Kukulska-Hulme et al. 2009). Both presence and flow terms have a positive impact on learning outcomes such as satisfaction, knowledge, and understanding (Kye and Kim 2008). Bolkan and Griffin (2018) analyzed the impact of technological intervention during a teaching on students' interest, attention, and motivation. They found that holding students' attention in the class environment is linked with their constant attention. Hidi stated that there is a correlation between attention and interest and long-term motivation played a determinant role in learning. Additionally, it is known that attracting attention can increase learning by affecting students' emotional experience (Linnenbrink-Garcia et al. 2010). Some studies argue that technologies in education such as 3D virtual world and AR increase students' attention levels (Dalgarno and Lee 2010; Dickey 2005). It is evident that AR-based education can have significant benefits by attracting and retaining students' attention. It can be stated that AR applications are better equipped to capture students' attention and interest due to their engrossing characteristics (Di Serio et al. 2013). Makransky and Lilleholt (2018) analyzed the emotional value of engrossing virtual reality in education and showed that students found simulations easy to use. This "usability" quality was seen to prevent distraction. Furthermore, it was observed that immersion gives rise to usability and a high presence. In this way, the experience was found to become more entertaining and motivating. Emotional experiences are necessary before presence, flow states can follow, and these emotions will continue to impact presence and flow. Emotional connections provide the opportunity for the experience of presence and flow (Scoresby and Shelton 2010).

The aim of this study is to determine the relationship between interest, usability, emotional investment, focus of attention, presence, and flow among university science students using AR technology. An ARI questionnaire developed by Georgiou and Kyza (2017) was used to examine the relationship between these variables. From this, a model was developed which includes usability, emotional investment, and presence variables, all of which have an impact on interest, focus of attention, and flow. Previous studies on immersion in the literature are largely related to the area of digital games. Therefore, there is a gap in the literature in relation to immersion in AR environments (Cheng and Tsai 2013). It is hoped

Fig. 2 ARI questionnaire factors



that this study will make a useful contribution in this respect. During the learning process, the significance of flow, presence, emotional investment, focus of attention, and their interrelationships were all examined and their effects on the use of instructional materials. From our survey of the literature, it is evident that insufficient attention has been given in previous studies to the factors affecting AR environments. Examination of these elements is essential for the development of more effective educational environments. This is an important issue for future education planning, and it is hoped that this study will make a useful contribution to the discussion.

Interest

Interest as a motivational variable is related to the psychological state in which attention is given to a particular target object, event, or opinion but which can fluctuate over time (Hidi and Renninger, 2006). Interest can be described as an individual's momentary experience of being captivated by an object as well as more lasting feelings that the target of the interest is enjoyable and worth further exploration (Harackiewicz et al. 2016). This definition shows that interest is a psychological attention state and that it affects a certain topic or object (Harackiewicz et al. 2016). In learning environments, the idea that interest is a permanent property that ensures greater student participation is accepted as an emotion that attracts students to a topic. It also enables students to form significant personal connections with a specified study field (Mazer 2013). Since emotions play an important role in attention, motivation, memory, decision-making, and behavior in terms of both performance and impact, there is an increasing interest in emotional factors that relate to user experience in human-computer interaction (Carvalho and Oliveira 2017). In line with this, studies show that emotional design elements have a low individual interest level for a topic and this could be used for students and individuals with low learning motivation (Uzun and Yıldırım 2018). Interactive learning environments (Hidi and Berndorff 1998; Hidi and Harackiewicz 2000; Hidi et al. 2004; Krapp 2000, 2002; Rathunde 1998; Renninger 1989, 1990, 2000) and the motivation of learners (Panksepp 2003) positively affect interest. Another study showed that, if a method attracts students' interest, then they experience positive emotions, and their interest and desire increases (Lin et al. 2014). It is stated that increasing student interest leads to increased attention; in this way, it is possible to increase interest and attachment to learning in an emotional sense (Mazer 2013; Titsworth 2001). In addition, Martin-Gutierrez et al. (2010) conducted a study in which it is seen that new technologies used in the learning environment increase interest in students. Furthermore, Kretschmer and Terharen (2019) stated that there is a positive correlation between an increase in the use of new technological products and the formation of interest status in students.

Studies of interest in the literature can be seen to approach the subject from three main perspectives: personal characteristics, learning environment related to personal interest, and situational interest (Renninger, Hidi, and Krapp 2014). The concepts of personal and situational interest are intertwined. In experimental research conducted into the concepts of interest and learning, Hidi and Renninger (2006) presented a four-stage model of interest. They explained the concept in terms of situational interest, encouraged situational interest, emerging individual interest, and improved personal interest. According to the model, students were able to sustain their internal work motivation through a prolonged interest in the subject, which in turn boosted their learning achievement (Ainley 2007). The learning environment is a critical factor in improving student interest (Linnenbrink-Garcia et al. 2010). Interest relies on the interaction between the student and the environment (Chen et al. 1999). Educators can increase the interest of students by developing different teaching methods and materials to improve interaction in the classroom.

Several references have been made in this section to the educational contribution of AR in increasing levels of interest in the classroom. In addition, Yu et al. (2019) proved that AR has a positive effect on interest in their experimental studies and Bressler and Bodzin (2013) showed that mobile AR science games have the potential to increase interest. In short, the interest of science teaching students to AR technology is an important factor in this context. The following hypotheses were tested in this study:

Hypotheses 1. Usability positively affects university students' interest

Hypotheses 2. Emotional investment positively affects university students' interest

Focus of Attention

In cognitive psychology, the concept of attention is defined as a process of directing our awareness to the relevant stimuli while ignoring unrelated stimuli in the environment (Kosslyn and Smith 2014). Georgiou and Kyza (2017) renamed "decreased perceptions" as the concept of "focus of attention." The "decreased perceptions" factor relates to reduced sensitivity of users to external stimuli in the physical world. "Focus of attention" refers to users' reduced physical world perception and increased focus on the AR application. In AR literature, focus of attention is more concerned with the concept of presence. The focus of attention depends on the degree of arousal that determines the observer's level of consciousness or unconsciousness of own behaviors when interacting with the environment (Waterworth and Waterworth 2001). AR increases focus of attention by combining virtual objects with real objects (Billinghurst 2002). Bekel, Heidemann, and Ritter (2005) developed a mobile AR application which enabled the focus of attention to be maintained through a specially designed device which users attached to their heads. Tran, Behrend, Fünning, and Arango (2018), in their research to measure the reactions of pilots in dangerous situations, found that the focus of attention of pilots in the group who used AR-Glasses was faster and more permanent than those who did not. Waterworth and Waterworth (2001) stated that virtual environments give individuals a sense of detachment from the real world and this has a negative effect in terms of the presence concept. They found that AR applications support the formation of presence status through the interaction of the real and virtual worlds and that presence emerges from focus of attention. These examples indicate the nature of the relationship of focus of attention and presence with AR. Many studies in the literature also conclude that there is a link between attention and presence. When levels of attention are greater, there is a greater sense of presence (Darken et al. 1999; Waterworth and Waterworth 2001; Witmer and Singer 1998). Hinde (2017) investigated the cognitive structures of individuals who watched films. He found that a comparison between presence and attention showed a common trend and positive correlation with time spent. Neuroscience research has begun to combine emotion and cognition as inseparable effects that lead to behavior and cognition in neural processes (Phelps 2006). Most fundamental of these processes is the relationship between emotion and attention through the amygdala. The amygdala is an area of the brain that is primarily associated with emotion but it also acts as a critical center for information flow and integration between different brain functions in cognitive-emotional interactions (Pessoa 2008). The science students' focus of attention when using AR technology is believed to be heavily dependent on this neural structure. The following hypotheses were tested using the model in this study:

Hypotheses 3. Presence positively affects university students' focus of attention

Hypotheses 4. Emotional investment positively affects university students' focus of attention

Flow

Flow depends on idea dynamics, movement, change, and rhythm. It is closely tied to time. Flow acts to prevent students getting bored and helps to develop challenging skills without producing anxiety (Whitson and Consoli 2009). In another description, flow is expressed as a psychological state in which an individual is fully immersed in an enjoyable activity (Giasiranis and Sofos 2017). Theoretically, three conditions are needed as prerequisites for flow: open targets, instant feedback, and balance between skill and challenges. Also, attention is an important component of flow theory (Egbert 2003; Gyllenpalm 2018). AR has two different potential effects: the first is developing students' performance and the second is providing flow experience that helps performance development (Giasiranis and Sofos 2017). Huang and Lin (2017) also reported that AR positively influenced the formation of flow experience. Flow is a psychological state that an individual tries to attain which brings satisfaction and enjoyment through being totally absorbed in the task (Giasiranis and Sofos 2017). Individuals focus on a target by preserving a feeling of control in the flow and a feeling that they are included in the action (Bressler and Bodzin 2013). Presence can be described as a situation in which an individual in an AR environment feels virtual objects in real worlds (Kye and Kim 2008). Alternatively, presence can be defined as a feeling of being in an environment although there is no physical presence. When someone focuses on an event, that person realizes what is happening around him, and this contributes to that person's presence (Scoresby and Shelton 2010).

Studies in the literature show that presence and focus of attention has a positive effect on flow. Kye and Kim (2008) analyzed the relationship between various factors in AR-based learning and found that there is a significant relationship between presence and flow. Although it is difficult to distinguish, according to Scoresby and Shelton (2010), flow is linked with individual experience, and individuals who feel that they are lacking in skill cannot have flow experience. However, presence is created by an environmental effect. Therefore, since the immediate surroundings are the environment where personal experience is found, its impact on behavior is inevitable, and it is expected that presence will create flow. The literature shows that Scoresby and Shelton (2010) used computer games to create flow experience and found that environmental factors have an effect and participants need to feel the presence. Similarly, other researchers asserted that presence is important for flow emotion to occur. Moreover, they said that presence must occur first before flow emotions and presence grows in strength and create flow (Barfield et al. 1995; Joo et al. 2013; Wang and Kang 2006).

Kim et al. (2014) employed a questionnaire using self-control, curiosity, focus of attention, and internal interest sub-dimensions adopted from Csikszentmihalyi's (1990) flow theory. They found that focus of attention created a more successful learning environment which had sufficient impact to create flow. Duffy and Healey (2018) studied music education and discovered that weak sounds from musical instruments reduced focus of attention and this situation disrupted the flow in the class environment. The formation of flow depends on setting goals that the individual can achieve and on providing immediate feedback to his/her studies. In this case, the individual develops a sense of focus and attention and supports the flow experience (Chen, Yu, and Hung 1999; Hoffman Kalsbeek and Novak, 1996; Skadberg and Kimmel, 2004). Other studies in the literature showed that focus of attention is the result of flow or is a necessary prerequisite for flow to occur (Csikszentmihalyi 1990; Krippner 1972; Madsen and Geringer 2008). In the abovementioned studies, it is emphasized that the focus of attention is a prerequisite for the flow experience or a normal result of the flow experience. Whichever situation applies, it can be safely stated that focus of attention is an important factor for the flow experience (Kim et al. 2014; Duffy and Healey 2018; Csikszentmihalyi 1990; Krippner 1972; Madsen and Geringer 2008). It can also be stated that the concept of focus of attentiont is complementary to the flow state. In short, university science students' flow with AR technology is a key factor in this context. The following hypotheses are tested in this study:

Hypotheses 5. Focus of attention positively affects university students' flow

Hypotheses 6. Presence positively affects university students' flow

Method

In this study, the correlational design is used to determine the relationship between interest, usability, emotional investment, focus of attention, presence, and flow of university students studying in the science education department who were using AR technology. The analysis was carried out using a structural equation model (SEM). A structural equation model is a technique used to test a hypothesis about the structure of relationships between measured variables in a given population (MacCallum and Austin 2000).

Participants

The sample included 180 university students studying in the science education department (32 males, 148 females). These students were training to become science teachers in secondary school and therefore can be considered as pre-service teachers. The students included in this study were voluntary participants studying in science departments. About 76% of the students stated that they had not previously heard of AR technology, while 24% stated that they had heard of it before. Details of the sample group, which was selected via the convenience sampling method, are shown in Table 1.

For this study, details were taken of the students' use of personal IT devices, Internet connection methods, and what purposes they used the Internet for in daily life. In addition, information technology (IT) skill levels, both in daily life and in the educational context, were recorded. A summary of this information is presented in Table 2.

Data Collection Tools

The ARI questionnaire developed by Georgiou and Kyza (2017) was employed to measure the immersion level of students while using AR applications. This uses a 7-point Likert-type scale ranging from "totally disagree" (1) to "totally agree" (7). The scale consists of 21 items, 3 dimensions, and 6 sub-factors. The dimensions of the scale were "total immersion," "engrossment," and "engagement." Sub-factors were "flow," "presence," "emotional investment," "focus of attention," "usability," and "interest." Flow refers here to a

Table 1 Demographic characteristics of sample group

	f	%
Gender		
Male	32	17.8
Female	148	82.2
Age	M	
Mean age	20	
Minimum age	17	
Maximum age	28	
Students' level	*f*	%
Freshman	28	15.6
Sophomore	48	26.7
Junior	55	30.6
Senior	49	27.2

Table 2 Summary of technology use by sample group

	f	%		*f*	%
Personal devices used			Stated purposes of Internet usage in daily life		
Desktop computer	35	19.4	Researching	171	95.0
Laptop	94	52.2	Playing games	102	56.7
Tablet	83	46.1	Spending time on social networks	152	84.4
Smartphone	179	99.4	Meeting new people	25	19.9
Other	2	1.1	Online shopping	129	71.7
Internet connection methods			Following news	141	78.3
Mobile internet (3G/4G/4.5G)	169	93.9	Spending time on video sharing websites	108	60.0
Wi-Fi	152	84.4	Chatting	69	38.3
Wired Internet connection	18	10.0	Using e-mail	82	45.6
Prior experience with AR			Doing homework	162	90.0
I do not know anything about AR	137	76.1	Listening to music	170	94.4
I have limited information about AR	43	23.9	Sharing files	107	59.4
IT use skill level in daily life			IT skill level for educational purposes		
1 point	2	1.11	1 point	2	1.11
2 points	13	7.22	2 points	18	10
3 points	67	37.22	3 points	69	38.33
4 points	73	40.55	4 points	69	38.33
5 points	25	13.88	5 points	22	12.22
Mean	3.59		Mean	3.51	

situation where individuals are engaged in an activity that only has a meaning under these circumstances. Presence refers to the feeling that involvement in a digital environment provides a deep sense of participation. The emotional attachment factor refers to the user's emotion, curiosity, and accomplishment. Focus of attention means that the user's perceptions of the physical world are reduced and focus is almost completely on AR. The usability factor is intended to measure how easily the user is able to use the application. The interest factor relates to the participant's attention to the application and the amount of time spent on it.

Georgiou and Kyza's (2017) studies were conducted in Greek and their articles published in English. In this study, as the participants were Turkish, the scale items had to be translated into Turkish by the authors. Three experts checked the Turkish and English items on the scale. English and Turkish language experts were also consulted in order to ensure, as far as possible, the validity of the measures. To ensure reliability, the regression weights of the items were calculated first. One item from the usability factors was excluded due to low regression weight. Cronbach's alpha value of the scale was calculated as 0.913 for this study. Each of the factors scored high for reliability in this study: "interest" ($\alpha = 0.89$), "usability" ($\alpha = 0.69$), "emotional investment" ($\alpha = 0.78$), "focus of attention" ($\alpha = 0.80$), "presence" ($\alpha = 0.87$), and "flow" ($\alpha = 0.79$). In this light, the measurement tool employed can be considered reliable.

Data Collection Process

Data were collected from university students in the education faculty during the 2018–2019 academic year. First, students were given general information about AR for 1 h, and then applications in the field of science were described, and sample videos were shown. Afterward, the advantages and disadvantages of using AR in science teaching were discussed with the students. In this way, it was ensured that the students were familiar with the idea of using AR in the teaching environment. Subsequently, three different science-related (*molecular structures, cell structure, and planets*) AR applications were introduced. These topics were selected from the options that the students would be likely to teach students in their classes after graduation. Though the content of each was different, the usage and features of the applications were similar. Five 7-in tablets were used, which were preinstalled with the applications required for AR. The students were divided into groups of five or six and were allowed a period of 1 h to test and familiarize themselves with the materials. Some visuals which illustrate the application process are presented in Fig. 3. The purpose of this training was to enable the students to see and experience how AR technology can be used in the field of education. In this way, the students (or pre-service teachers) were informed about AR applications and how they work, and their general awareness was raised. The content was not important at this stage, and the level of the pre-service teachers'

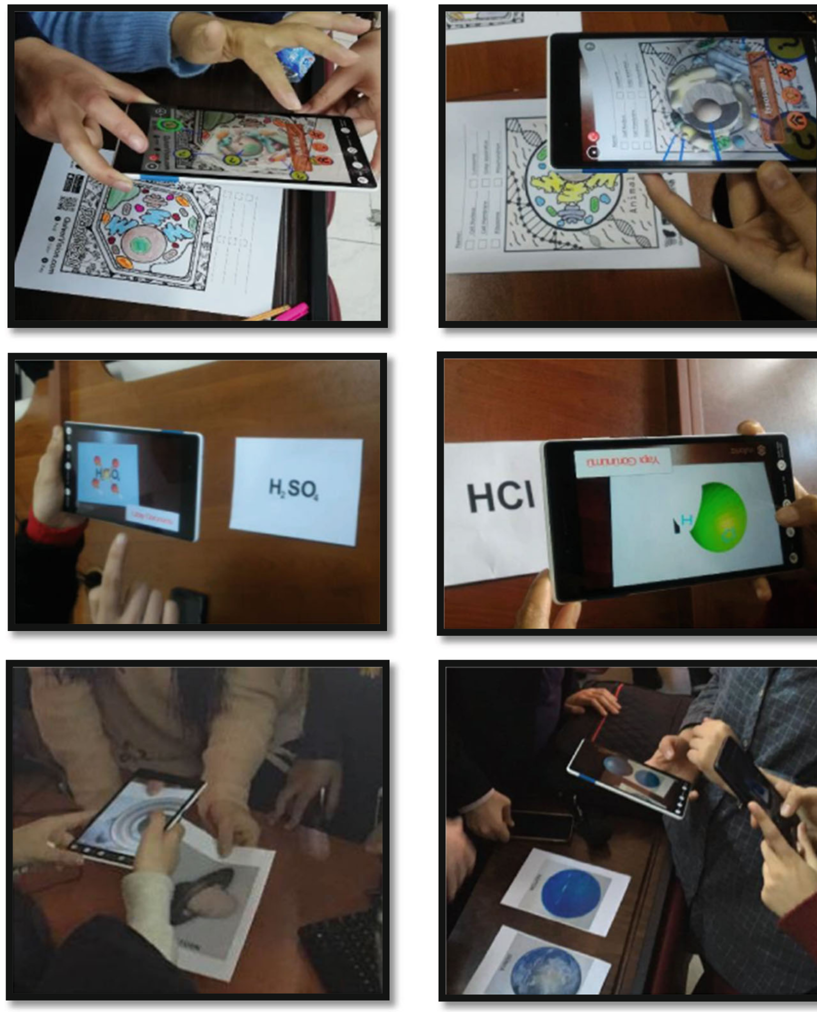


Fig. 3 Some visuals demonstrating the implementation process

existing learning was not investigated. The important aspect here was the immersion experience when using AR applications. After two hours of teaching, the questionnaire was issued to the students, and data were collected. The course was given separately to each class, and data collection took place over a period of 1 month. Participation in these classes was on a voluntary basis.

Data Analysis

SEM analysis was used to determine the relationship between interest, usability, emotional investment, focus of attention, presence, and flow in university students studying in the science education department who used AR technology. First, assumptions such as extreme values, missing data, normality, multicollinearity, and variances of variables for SEM analysis were checked. Coefficients of kurtosis and skewness, which were calculated based on six variables in the study, initially met the criteria of normality. Extreme values and missing data were checked and corrected. The Levene test was conducted to determine variance equality, and it was seen that all factors except one showed variance equality. When variance is not equal, it is recommended that the variance of variables should not exceed 10. All these ratios were below 10. Therefore, it can be said that the variances of the variables were equal (interest = 0.1.88, $p > 0.05$; usability = 2.50, $p > 0.05$; emotional investment = 1.54, $p > 0.05$; focus of attention = 1.41, $p > 0.05$; presence = 2.09, $p > 0.05$; flow = 2.951, $p < 0.05$). Variables showed a linear structure. As the sample size for this study was 180 participants, it can be said that is a limitation. Medium and high relationships were found between variables (see Table 3). Pearson's correlation test was conducted to determine the relationships between dependent variables in the study, as these variables met linearity assumptions (Field 2009). When the correlation between variables was smaller than 0.85, the multicollinearity assumption was met. Therefore, we can confirm that in this case multicollinearity was indeed met. The model in this study was tested via Amos 20.

Table 3 Relationship levels between variables

	Interest	Usability	Emotional investment	Focus of attention	Presence	Flow
Interest	1					
Usability	0.343**	1				
Emotional investment	0.653**	0.197**	1			
Focus of attention	0.622**	0.133	0.728**	1		
Presence	0.433**	0.111	0.544**	0.681**	1	
Flow	0.453**	0.140	0.556**	0.696**	0.647**	1

** $p < .01$

Findings

To determine the relationship between interest, usability, emotional investment, focus of attention, presence, and flow for university students studying in the science education department using AR technology, descriptive results for each factor and analyzed model were presented. Students' factor averages are presented in Table 4.

Based on related literature, the model tested in this study is validated and presented in Fig. 4 with estimated path coefficients. Additionally, the significance of these paths is presented in Table 5. Based on these findings, all paths between all variables were significant.

The goodness of fit of the obtained model results was checked. Accordingly, Chi-Square, as one of the goodness of fit coefficients, was obtained as $\chi 2 = 235.12$ (df = 158, $p < .05$). Based on this result, the Chi-Square value would be regarded as insignificant in the literature. However, this value is extremely sensitive to the size of the sample. Alternatively, a different calculation is recommended which requires dividing the Chi-Square value by the degree of freedom (Kline 2010). According to these ratios and various other indexes, this model is acceptable and has a perfect fit. RMSEA (Root Mean Square Error of Approximation), AGFI (Adjusted Goodness of Fit Index), and NFI (Normed Fit Index) goodness of fit indexes were calculated. The value ranges for these indexes were referenced in Hair et al. (1998), Kline (2010), and Raykov and Marcoulides (2008) and are presented in Table 6 with the goodness of fit values. In this study, the CFI (comparative fit index) index value is 0.884. Although this lies below the level of generally acceptable values, this value can be used here due to sample size.

Table 4 Descriptive data for each factor

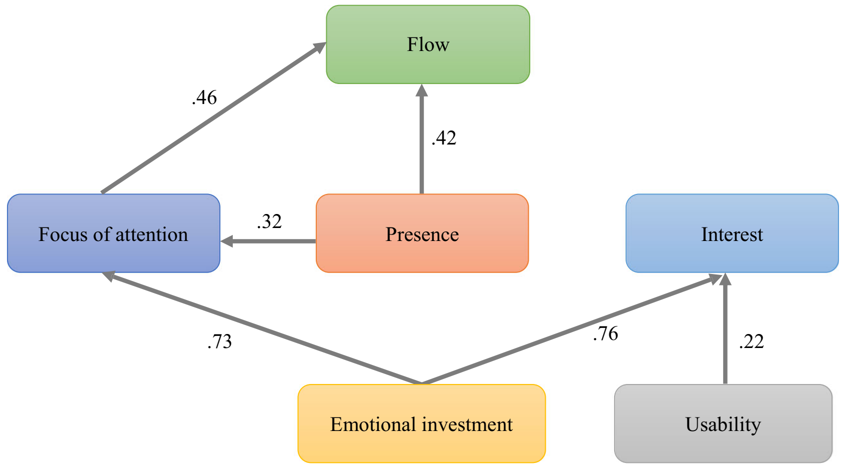
Factors	M	sd
Interest	6.28	0.831
Usability	5.93	1.134
Emotional investment	5.69	1.134
Focus of attention	5.51	1.282
Presence	5.11	1.415
Flow	5.20	1.481

This model investigated factors affecting university students' flow experiences while using AR applications. It showed that the effects of emotional investment, focus of attention, and presence on flow explained 71% of the total variance. Presence ($\beta = 0.42$) had a direct effect on flow. Emotional investment and presence had an indirect effect on flow, but these effects were not significant. Emotional investment ($\beta = 0.73$) and presence ($\beta = 0.32$) had a direct effect on focus of attention. In addition, usability ($\beta = 0.22$) and emotional investment ($\beta = 0.76$) had a direct effect on interest. Full details of this are laid out in Table 7.

Discussion, Conclusion, and Recommendations

The purpose of this study was to determine the relationship between interest, usability, emotional investment, focus of attention, presence, and flow among university students studying in the science education department who used AR technology. First, students' general use of technology was examined. Findings showed that 99% of students used a smartphone and 52% of them used a laptop. Students' desktop computer usage rate was low (19%). These results were due to benefit expectations and perceptions from technological tools and also to the ease of use of these technological products. According to Davis et al. (1989), people's reasons for using technology include their perceived usefulness and perceived ease of use. The ease of use of mobile devices is also associated with increased motivation and consequently increased academic achievement (Fonseca et al. 2014). Additionally, these tools enable people to acquire more knowledge and to improve understanding (Nuanmeesri et al. 2019). When the data was analyzed on students' preferred Internet connection method, 94% of the students were found to use mobile Internet, and 84% used Wi-Fi. Students generally used the Internet for following purposes: research (95%), homework (90%), listening to music (94%), social networking (84%), shopping online (72%), and following news (78%). These

Fig. 4 Tested model in this study



results are due to individual differences, and, according to Agarwal and Prasad (1999), individual differences are important in information technology use. In addition, students reported their daily usage of technology (M = 3.59) and their use of technology in educational life (M = 3.51) to be at a moderate level. These results may be accounted for by acceptance and adoption of information technologies (Agarwal and Prasad 1999). Finally, 76% of the students stated that they had not used AR technology before. The fact that they had not previously encountered this technology may have led to a novelty effect. This is a commonly-recognized phenomenon when people are first introduced to new technology'. This situation presents an opportunity for individuals to develop a positive attitude toward technology. However, with the passage of time, individuals who are accustomed to technology may not maintain the same positive attitude. In this study, the students the students may have formed their opinions while experiencing the novelty effect as they were engaged in a short-term activity. This can be regarded as one of the limitation of the study.

This study investigated factors affecting university students' flow experiences while using AR applications. Results showed that the effects on flow of emotional investment, focus of attention, and presence on flow explained 71% of the total variance. According to our model, the effect of focus of attention and presence on flow was significant. However, focus of attention had only a direct effect on flow, but this effect was not significant. Focused attention is a fundamental component of the flow experience (Harris et al. 2019). It is necessary to create a focus of attention for flow experience to result (Csikszentmihalyi 1990; Duffy and Healey 2018; Kim et al. 2014; Krippner 1972; Madsen and Geringer 2008). Since presence is a prerequisite for flow state, it contributes to flow experience (Barfield et al. 1995; Joo et al. 2013; Scoresby and Shelton 2010; Wang and Kang 2006). Feeling the presence of something that may or may not actually exist in an environment, especially feeling the presence of objects that do not exist in reality but only with the AR technology can contribute greatly to the flow experience by increasing focus of attention. Studies in the literature show that the presence and the focus of attention are related to flow experience. Csikszentmihalyi (1990), Duffy and Healey (2018), Kim et al. (2014), Krippner (1972), and Madsen and Geringer (2008) all maintained that focus of attention is important for flow experience and for enhanced flow experience.

This study found that university students' "emotional investment" and "presence" influence their "focus of attention". As emotion is generally believed to increase interest in a subject, it may be expected that interest would increase the level of attention. In addition, in AR technology, the sensing of objects that do not actually exist is thought to be a factor which acts to increase attention. Huang et al. (2019) stated that using AR in science education increases the sense of presence. Scoresby and Shelton (2010) investigated the effects of educational video games on presence and flow and argued that

Table 5 Tested hypothesis results

Hypothesis	Methods	Standardized regression weights	*p*	Results
H_1	Usability → interest	0.223	0.003	Accepted
H_2	Emotional investment → interest	0.755	0.000	Accepted
H_3	Presence → focus of attention	0.321	0.000	Accepted
H_4	Emotional investment → focus of attention	0.725	0.000	Accepted
H_5	Focus of attention → flow	0.461	0.000	Accepted
H_6	Presence → flow	0.424	0.003	Accepted

Table 6 Goodness of fit value range and model value

Goodness of fit	Perfect	Acceptable values	Model values	Fit
χ2/df	< 2	2–5	1.488	Perfect
RMSEA	≤ 0.05	≤ 0.08	0.052	Perfect
AGFI	≥ 0.95	≥ 0.85	0.846	Acceptable
NFI	≥ 0.95	≥ 0.90	0.896	Acceptable

emotional attachment affects flow and presence as long as individuals are in the virtual environment. Kim et al. (2014) aimed to increase competence and autonomy in their research by using skill-balancing strategy in computer-aided instruction. More interesting applications had the effect of increasing focus of attention. In light of all these findings, it can be argued that when AR is used in science education, presence in students may be increased. In turn, emotional attachment affects presence, and AR applications can provide students with more opportunity to improve their focus of attention.

Our results showed that university students' "usability" and "emotional investment" influenced their "interest." It was seen that the interest of students who used AR applications and interacted with computers/tablets/smartphones increased significantly. Because of the ease of use of these devices, it is not necessary to concentrate intently on the use of the application. This acts to prevent distraction and attention improves, presence is felt more strongly, and interest increases. Scoresby and Shelton (2010) concluded that personal interest is related to emotional investment. Also, when content is appropriate for personal interest, it is easier for presence and flow experience to follow (Scoresby and Shelton 2010). It was seen that the use of tablets in this study increased students' attention and motivation. Also, individuals experienced a positive emotional state by forming significant personal connections with the topic. It was found that this emotional state has a significant effect on interest. Additionally, it is believed that new technological applications, combined with tools which have high usability in the learning environment, can serve to attract interest as students gain more experience.

Table 7 Direct, indirect, and total effects

Variables			
Dependent variable Flow	Direct effect	Indirect effect	Total effects
Independent variable			
Emotional investment	–	0.334	0.334
Focus of attention	0.461	–	0.461
Presence	0.424*	0.148	0.572*
$R^2 = 0.714$			
Dependent variable Focus of attention	Direct effect	Indirect effect	Total effects
Independent variable			
Emotional investment	0.725*	–	0.725**
Presence	0.321*	–	0.321**
$R^2 = 0.952$			
Dependent variable Interest	Direct effect	Indirect effect	Total effects
Independent variable			
Usability	0.223*	–	0.223**
Emotional investment	0.755*	–	0.755**
$R^2 = 0.677$			

*$p < .05$

No significant relationship was found between presence and interest. Presence and interest are fed from two different perspectives. Presence relates to the form of the application, while interest relates to the content (Slater 2003). This may be why there was found to be no relationship between presence and interest in this study. The content of the applications was already known to the participants. On the other hand, they encountered the AR applications for the first time. Therefore, presence may be created but not interest.

The following recommendations can be made, based on the findings of this study:

- Since most pre-service teachers declared that they did not know anything about AR implementation, it is recommended that pre-service science teachers are given training on AR before starting work.
- As it was found that focus of attention and presence affect the flow, designers are advised to design AR in a way which easily enables the capture of attention and reality perception in order to generate flow in the participants.
- The sense of presence must be created to achieve flow experience in AR applications. To achieve this, user profiles should be considered and familiar environments, objects, concepts, and visuals employed.
- The findings indicate that presence and emotional investment have a direct effect on focus of attention. Therefore, in AR applications, realistic objects and environments should be used to enable students to feel the presence, enabling them to establish an emotional connection with the application and improving levels of attention.
- Individual emotional attachment should be sustained to aid focus of attention in AR applications. Applications should be developed based on real-life situations and individuals' previous life experiences.
- This study shows that usability has a direct effect on students' interest. Therefore, it is recommended that a simple, uncomplicated, and straightforward design should be used in order to increase interest.
- According to the results of the research, 99% of the students use smartphones. Therefore, AR applications compatible with smartphones should be further developed.

- The research indicates that students' use of technology in daily life and in an education context is already at a high level. Therefore, the use of AR applications should be encouraged in all classes.
- As the sample size for this study was limited, it is important that model studies are conducted with larger samples in future studies.
- In this study, students' opinions may have been influenced by the novelty effect of short-term involvement with technology that was new to them. In future studies, it is recommended that students use AR technology for longer periods in order to eliminate as far as possible the effects of innovation.
- In future studies, all variables used in the model should be examined through qualitative research, and the correlations investigated in depth.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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