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Research Article

Exploring intention to use augmented and virtual reality applications as educational tools

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Abstract: In today's educational landscape, students have access to enriched learning environments through augmented and virtual reality (AR/VR) applications. Effective digital learning depends on identifying the key factors and learner attitudes that influence engagement and task performance. We focused more on preservice teachers' intentions to use AR/VR applications as instructional tools, guided by the Theory of Planned Behavior (TPB) framework. A total of 306 preservice teachers participated in the Exploratory Factor Analysis (EFA), 286 in the Confirmatory Factor Analysis (CFA), and 341 in the Structural Equation Modelling (SEM) phase. To identify relevant constructs and beliefs, the researchers developed a questionnaire grounded in TPB-based hypotheses. The questionnaire demonstrated high internal consistency, with a McDonald's Omega reliability coefficient of .95. Three factors—perceived behavioral control, subjective norm, and attitude toward behavior—accounted for 47% of the variance. Empirical findings confirmed the relevance of all three factors in predicting behavioral intention. Specifically, the relationship between attitudes towards behavior and behavioral intention was moderate, between subjective norm and behavioral intention was weak, and between perceived behavioral control and behavioral intention is strong. The findings may guide practitioners in developing and evaluating TPB-based interventions to enhance preservice teachers' intentions to use AR/VR applications as educational tools. The study concludes by identifying gaps within the existing framework and suggesting directions for future research.

1. INTRODUCTION

Information technologies allow individuals to access a wide range of information and exert a significant influence on various aspects of daily life (Makridakis, 2017). Consequently, individuals no longer merely retain information but rather create, access, and apply knowledge purposefully (Wagner, 2010). However, the mere integration of technology into educational settings is not sufficient. As Santos and Castro (2021) emphasize, educators must possess the

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necessary knowledge and competence to effectively utilize technological tools. In order to benefit from technology-enhanced learning environments, educators need to use educational technologies in alignment with their intended pedagogical purposes. While numerous studies grounded in the Technological Pedagogical Content Knowledge (TPACK) framework have been conducted in science and mathematics education, researchers have pointed out the lack of robust theoretical and practical frameworks that adequately support and guide teachers in integrating technology into classroom practices. Therefore, it is essential for teachers to stay informed about technological advancements and leverage them effectively within educational settings (Sermet & Demir, 2020). Among these tools, computers remain one of the most widely used in instructional settings; however, their unplanned or improper use can yield both positive and negative consequences.

Artificial Intelligence (AI) is increasingly pervasive in both personal and professional domains, influencing various aspects of individuals' daily lives. People's acceptance of AI is likely shaped by their general attitudes toward technology. One of the primary aims of our study was to develop an instrument for assessing broad attitudes toward AI in both academic and practical settings, while also exploring its conceptual foundations. This effort involved the initial conceptual and statistical validation of a newly developed scale. Another objective was to document general perceptions of AI applications as well as reactions to specific examples (Schepman & Rodway, 2020). Accordingly, AI tools can be planned and implemented purposefully, depending on their intended use (Johnson et al., 2016). Through the use of educational software, educators are able to offer students enriched learning environments. The integration of 3D visual content into course materials enables students to mentally visualize, rotate, and manipulate objects as if they were tangible (Demitriadou et al., 2020; Osipenko & Guseva, 2022). This feature facilitates the teaching of complex or abstract environments that are otherwise difficult to replicate in real-world settings (Cennamo & Kalk, 2019).

With the emergence of immersive experiences that were previously unattainable, technologies such as AR and VR have fundamentally transformed the ways in which students engage with instructional materials. The potential for experiential learning has significantly expanded through AR and VR applications, ranging from interactive simulations of complex scientific concepts to virtual field trips. Today, AR is widely used across various sectors, including entertainment, production, engineering, healthcare, and education. However, the literature often reveals a conceptual overlap between AR and VR, as definitions of augmented reality frequently reference virtual objects, leading to confusion between the two. VR, in contrast, involves creating computer-generated environments that simulate reality, providing users with a sense of presence in a non-physical world (Wu *et al.,* 2013). Rather than replicating the real world, VR generates immersive, simulated environments that evoke a sense of realism. The effectiveness of various non-visual modalities in AR/VR learning environments has also been investigated in the context of STEM education, particularly for students who are blind or have low vision (BLV) (Shankar et al., 2023). The study compared a natural language condition—offering detailed verbal explanations—with a vibro-audio condition that combined device vibrations and auditory input. Findings suggest that both modalities are comparably effective in facilitating the interpretation of graphical content, highlighting the potential of AR/VR technologies to accommodate diverse sensory needs in educational contexts.

This study underscores the vital role of sensory modalities in AR/VR technologies, particularly in enhancing inclusion and accessibility within educational settings. Moreover, educational leaders must consider strategies for optimizing the implementation of diverse VR/AR applications in instructional contexts (Kraus *et al.,* 2021). One study specifically explored the potential of AR in mathematics education, highlighting its ability to bridge the gap between abstract and concrete concepts. The use of GeoGebra AR, for instance, allows for the projection of three-dimensional graphs and objects into real-world environments, thereby facilitating spatial reasoning and conceptual understanding. This tool enables students to embed

3D mathematical objects into their surroundings and explore them from multiple angles, while guided image-based exercises support the recognition of real-life applications of mathematical concepts (Tomaschko, 2020).

AR significantly enhances data visualization by making complex information more accessible and comprehensible. It also supports language learning through features such as real-time translations and pronunciation assistance (Shankar et al., 2023). In contrast, VR immerses users in entirely computer-generated environments that are detached from the physical world (Schott & Marshall, 2018). While VR aims to simulate a complete sense of presence through digital elements such as sound, video, and graphics, AR integrates these virtual elements into the real world to augment users' perception of their physical environment. In essence, while VR replaces reality with a virtual construct, AR overlays digital content onto the existing physical surroundings.

The continuum between reality and virtuality is illustrated through the mixed reality model depicted in Figure 1 (Milgram & Kishino, 1994).

Figure 1. *Simplified representation of a virtuality continuum*

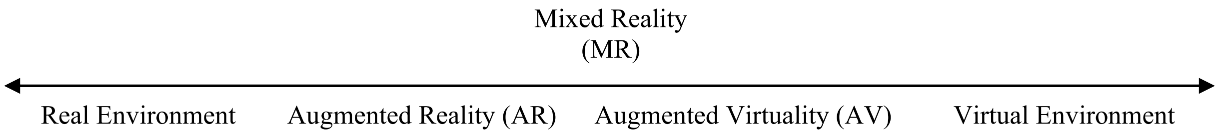


Figure 1 presents a simplified representation of a virtuality continuum. When Figure 1 is examined, reality increases as one moves to the left of the diagram. In addition, augmented reality occurs through virtual add-ons integrated into the real environment. To the right of the diagram, an environment composed of virtual objects is created to simulate a sense of reality. With the inclusion of real objects in the virtual environment, augmented virtuality emerges.

1.1. Augmented Reality (AR) and Virtual Reality (VR) Used as Educational Tools

The development of educational technology, particularly the introduction of AR and VR, marks a significant turning point in the history of teaching and learning approaches. According to Shankar (2023), educational technology was initially employed to enhance traditional teaching techniques through digital tools. A major milestone in this evolution was the emergence of interactive software and the internet in the late 20th century, which laid the groundwork for more sophisticated and immersive educational technologies. Furthermore, the integration of AI into the curriculum has not been achieved, largely due to the difficulty of designing effective AI content for K–12 students and the lack of funding and support for curriculum development, especially in developing countries such as Kenya. Many educators are ill-prepared to teach artificial intelligence (AI), as there are limited professional development opportunities and AI is not currently included in the curriculum. To address this, Kenya urgently needs to develop an AI curriculum and implement a comprehensive training and professional development program to equip educators with the knowledge, skills, and attitudes required to effectively teach AI, either as a standalone subject or within a cross-curricular framework (Fundi *et al.,* 2024).

In recent years, a growing body of literature has explored the use of AR and VR as educational tools. AR and VR technologies have been found to enhance engagement and motivation (Lin & Wang, 2021; Teo *et al.,* 2008). Studies have shown that AR and VR applications can offer immersive and interactive experiences, making learning more enjoyable and engaging (Roopa *et al.,* 2021). Additionally, the use of AR and VR technologies has been found to increase learners' motivation by making learning more relevant and personalized. Several studies have reported that the integration of AR and VR technologies can enhance learning outcomes (Coban, 2022). Furthermore, AR and VR technologies can provide realistic simulations of real-world scenarios, enabling learners to develop problem-solving and decision-making skills (Papanastasiou *et al.,* 2019). These technologies can also enhance accessibility and inclusivity in education. For example, AR and VR can offer virtual field trips, which are often more accessible and cost-effective than traditional ones (Kenna & Potter, 2018). Using data from previously conducted studies and real-world applications, Shankar (2023) presents an overview of the effects of VR and AR in education. Their research demonstrates how VR can be used to build captivating and immersive learning environments by transporting students to virtual locations that support hands-on learning. AR overlays digital information onto the physical environment, enhancing traditional educational resources with guided field excursions and interactive textbooks. This study highlights the value of VR and AR in promoting collaborative learning and addressing the individual needs of students, including those with special needs.

Some of the best practices identified in the literature include providing learners with clear learning objectives, designing activities that align with those learning objectives, and offering learners feedback on their performance (Hamilton *et al.,* 2021). Additionally, studies have emphasized the importance of integrating AR and VR technologies into the curriculum in a thoughtful and intentional manner. These technologies can be used to tailor content to learners' learning styles, pace, and preferences, thereby making learning more effective and efficient (Alalwan *et al.,* 2020). Overall, the literature suggests that AR and VR technologies have the potential to transform education by enhancing engagement, motivation, and learning outcomes. With the introduction of VR, the educational environment has undergone a significant transformation that has redefined the idea of immersive learning. VR's capacity to generate virtual environments has opened new avenues for hands-on learning. Within the walls of a classroom, students may now conduct intricate scientific simulations, visit historical locations, and participate in interactive learning activities. In addition to increasing engagement, this shift toward an immersive educational experience aims to improve information retention and foster the development of practical skills (Shankar *et al.,* 2023).

1.2. Preservice Teachers' Intention to Use AR/VR as Educational Tools

Preservice teachers' intention to use AR/VR as educational tools can be influenced by several factors, including their perceived usefulness, ease of use, self-efficacy, and attitudes toward technology integration in the classroom. Perceived usefulness refers to the extent to which preservice teachers believe that using AR/VR as educational tools can enhance their students' learning experiences (Coban *et al.,* 2022). If preservice teachers perceive that using AR/VR can help their students better understand difficult concepts or engage them in the learning process, they are more likely to intend to use these technologies. Ease of use refers to the extent to which preservice teachers believe that using AR/VR as educational tools is easy and straightforward (Kline, 2011). Self-efficacy refers to preservice teachers' confidence in their ability to use AR/VR as educational tools effectively (Lee & Shean, 2020). If preservice teachers feel confident in their ability to use these technologies and believe that they can overcome any challenges or obstacles they may encounter, they are more likely to intend to use them. Attitudes toward technology integration in the classroom refer to preservice teachers' beliefs and opinions about using technology in educational settings (Huang *et al.,* 2010). If preservice teachers have positive attitudes toward technology integration and believe that using technology can enhance their teaching and their students' learning, they are more likely to intend to use AR/VR as educational tools. AR also has a wide-ranging influence on language acquisition, since it offers pronunciation assistance and real-time translations. It simplifies complex content through data visualization (Shankar, 2023). Overall, preservice teachers' intention to use AR/VR as educational tools is shaped by their perceptions of the usefulness and ease of use of these technologies, their self-efficacy, and their attitudes toward technology integration (Anderson & Maninger, 2007). Teacher education programs and professional development opportunities can be designed to address these factors and increase preservice teachers' intention to use AR/VR in their future classrooms. This is the main point of the study.

1.3. Theory of Planned Behavior (TPB)

TPB is a widely accepted model for understanding human behavior (Ajzen, 2012; Ajzen & Fishbein, 2008). According to this theory, a person's behavior is influenced by their attitudes, subjective norms, and perceived behavioral control (Ajzen & Fishbein, 1980). To understand TPB, the Theory of Reasoned Action (TRA) should first be explained, as TRA forms the foundation of TPB (Fishbein & Ajzen, 1975; Ajzen, 1985; Schifter & Ajzen, 1985). According to TRA, behavior is associated with three main factors, and intention can be explained by attitude toward behavior and subjective norm. TRA can be formulated as $B \sim I \propto [w1AB + w2SN]$. In this equation, B symbolizes behavior of interest, AB represents the attitude toward performing behavior, w denotes weighting parameters, and SN refers to the subjective norm. The stronger the intention, the more likely the behavior is to occur; and when AB and SN are evaluated positively, the individual is more likely to form a positive intention to perform the specific behavior (Ajzen, 1985; Ajzen & Madden, 1986).

TBP includes the dimension of perceived behavioral control. Perceived behavioral control can be used directly with the intention to estimate behavior. Figure 2 illustrates the related factors and beliefs affecting them: "behavioral beliefs", "normative beliefs", and "control beliefs" (Fishbein & Ajzen, 1975; Ajzen, 1985; Shifter & Ajzen, 1985; Ajzen & Madden, 1986; Ajzen, 1991; Ajzen, 2002; Erten, 2000). The TPB model proposes that the most important determinant of behavior is an individual's intention to perform that behavior. Attitudes refer to the positive or negative evaluation of the behavior; subjective norms involve perceived social approval or disapproval of performing the behavior; and perceived behavioral control relates to internal and external barriers. As shown in Figure 2, "perceived behavioral control" may serve as a predictor of behavior. Based on the TPB, we can explore the potential use of AR and VR applications as educational tools by examining these three factors. For example, educators could provide students with information about the potential benefits of using AR and VR technologies in education to influence their attitudes towards these technologies (Bonetti *et al.,* 2018). Additionally, educators could promote a culture that supports the use of AR and VR technologies in education to influence subjective norms (Mazman, 2019). Finally, educators could offer training and support to help students develop their skills in using AR and VR technologies, thereby increasing their perceived behavioral control (Karademir & Erten, 2013). Overall, TPB provides a useful framework for examining the potential use of AR and VR applications as educational tools. By analyzing "attitudes", "subjective norms", and "perceived behavioral control", educators can better understand how to integrate these technologies effectively into the classroom to enhance student learning and engagement (Alalwan *et al.,* 2020).

Several stakeholders are involved in the integration of AR and VR in education, including administrators, legislators, and teachers. Dutt (2022) examines the long-term effects of Extended Reality (XR) applications in education on learners with disabilities. Their research provides a comprehensive analysis of how XR technologies—which encompass both VR and AR—can benefit students with impairments by increasing motivation, facilitating communication, supporting the development of cognitive skills, and enhancing the educational process.

Attitudes: The first factor that influences behavior is attitude (Ajzen & Fishbein, 1980). In the context of AR and VR applications, attitudes refer to an individual's beliefs about the effectiveness and usefulness of these technologies as educational tools. Positive attitudes towards AR and VR technologies increase the likelihood of their use for educational purposes (Huang *et al.,* 2010).

Subjective norms: The second factor that influences behavior is subjective norms (Fishbein & Ajzen, 1975). This refers to the social pressure an individual perceives from others to engage in a particular behavior. In the context of AR and VR applications, subjective norms refers to the perceived expectations of others (such as teachers or peers) regarding the use of these technologies in education (Karacan & Polat, 2022; Sadaf *et al.,* 2012).

Perceived behavioral control: The third and final factor that influences behavior is perceived behavioral control (Armitage & Conner, 1999). This refers to an individual's belief about their ability to engage in the behavior. In the context of AR and VR applications, perceived behavioral control refers to the individual's confidence in their ability to use these technologies effectively in an educational setting (Sadaf *et al.,* 2012). In this study, we examine how the Theory of Planned Behavior applies to teachers' intention to use AR and VR applications as educational tools.

The main purpose of the study is to construct a TPB-based model that predicts the use of AR and VR applications as educational tools. Within the scope of the research, the following research questions were addressed:

1. Does the attitude toward AR and VR applications have a positive effect on the intention to use AR and VR applications as educational tools?
2. Does the perceived behavioral control have a positive effect on the intention to uses AR and VR applications as educational tools?
3. Does subjective norm have a positive effect on the intention to use AR and VR applications as educational tools?

In accordance with these research questions, the following hypotheses were developed;

H1: Attitude toward AR and VR applications has a positive effect on the intention to use AR and VR applications as educational tools.
H2: Perceived behavioral control has a positive effect on the intention to use AR and VR applications as educational tools.
H3: Subjective norm has a positive effect on the intention to use AR and VR applications as educational tools.

2. METHOD

2.1. Research Design

In this study, which employed a quantitative research method, both descriptive and predictive statistical methods were used for analysis. In addition, structural equation modeling (SEM) was applied to test the relationships between latent variables.SEM is an increasingly utilized multivariate analysis tool in scientific research for examining and evaluating complex causal interactions. Compared to other modeling techniques, SEM allows for the testing of both direct and indirect effects within hypothesized causal relationships. The model enables the analysis of interactions among multiple variables and reveals the relationships between them from a holistic perspective. It also verifies the fit between the structural model and the observed data, while accounting for measurement errors. Unlike other statistical methods, SEM is based on a confirmatory rather than a new approach (Kline, 2011). The primary reason for using this method is that it allows for the simultaneous testing of multiple dependent variables believed to be associated with more than one independent variable in the model. Another reason is the novelty of this study, as recent research exploring the intention to use augmented and virtual reality applications as educational tools is lacking.

2.2. Participants

Based on the table, male participants constituted 20.8% of the total sample, while female participants made up 79.2%. Students enrolled in the Science Education program accounted for 34.9%, those in Primary Education for 18.5%, and those in Mathematics Education for 46.6% of the total participants. The participants' profile is presented in Table 1.

Table 1. *Participants' profiles*

Demographic variables	Category	*Frequency (f)*	%
Gender	Male	71	20.8
	Female	270	79.2
Program	Science Education	119	34.9
	Primary Education	63	18.5
	Mathematics Education	159	46.6
Total		341	

2.3. Research Instruments and Procedures

TPB is considered a useful model. The statistical relationship between attitude and behavior is high and significant when evaluated according to the correspondence principle. Four factors are important for explaining the relationship between behavior and attitude to a high degree: "target", "action", "context" and "time" (Ajzen & Fishbein, 1980). Accordingly, the questionnaire items designed to measure intention, norm and perceived control were developed by considering this criterion (Ajzen, 1991; Ajzen, 2002). A questionnaire from a previous study (Can & Hiğde, 2022) was reviewed and utilized by the researchers. The scale was adapted for the present study by revising the items based on the feedback of the three field experts, shifting the focus from STEM content to AR and VR contexts. In this way, a new version of the scale was developed in alignment with the research questions as well as the TPB framework (Ajzen & Fishbein, 1977; Ajzen, 1991; Ajzen, 2002; Erten, 2000).

Factor analysis was performed to ensure the structural validity of the scale. The PASW 29 program was used for the analysis. Data for the exploratory factor analysis were collected from 306 participants. Male participants constituted 46.4% of the total sample, while female participants accounted for 53.6%. Students enrolled in Science Education made up 36.6%, those in Primary Education 34.3%, and those in Mathematics Education 29.1% of the total participants. Prior to the factor analysis, the suitability of the data was tested using Kaiser-Mayer-Olkin (KMO) and Bartlett's tests. The KMO coefficient was calculated as .845 ($p< .05$). McDonald's Omega coefficients for the dimensions were calculated as follows: Perceived Behavioral Expectation (A1), Perceived Behavioral Evaluation (A2) = .945, Normative People Institution (A3) = .843, Motivation (A4) = .844, Perceived Behavioral Difficulties (A5) = .924, Perceived Behavioral Ease (A6) = .896, Attitudes Towards Behavior (A7) = .857, Subjective Norm (A8) = .925, Perceived Behavioral Control (A9) = .879, and Intention Toward Behavior (A10) = .906. The overall McDonald's Omega reliability coefficient for the scale was found to be .944. As a result of the factor analysis, 48.855 % of the total variance was explained. Considering that variance rates between 40% to 60% are deemed acceptable in factor analysis (Scherer, 1988), the variance explained in this research is considered sufficient. Items with factor loadings below .30 were removed from the scale. Specifically, items A1.1, A1.3, A1.4, A1.16, A1.22, and A1.23 were excluded from the analysis. The factor loadings of the scale according to EFA are presented in Table 2.

Confirmatory Factor Analysis (CFA) was conducted on data collected from a separate group. AMOS 23 was used for CFA. Data were collected from 286 participants. Male participants constituted 60.5% of the total sample, while female participants accounted for 39.5%. Students enrolled in Science Education comprised 36.0%, those in Primary Education 29.4%, and those in Mathematics Education 34.6% of the total participants. McDonald's Omega coefficients for the dimensions were calculated as follows: Perceived Behavioral Expectation (A1) = .978, Perceived Behavioral Evaluation (A2) = .977, Normative People Institution (A3) = .854, Motivation (A4) = .891, Perceived Behavioral Difficulties (A5) = .885, Perceived Behavioral Ease (A6) = .976, Attitudes Towards Behavior (A7) = .921, Subjective Norm (A8) = .871, Perceived Behavioral Control (A9) = .862, and Intention Toward Behavior (A10) = .743. The overall McDonald's Omega reliability coefficient for the data collection tool was found to be .970. Fit indices were evaluated to assess model fit (χ^2 =11068.416 df=4514, χ^2/df=2.452, $p< .01$, CFI=.977, TLI/NNFI=.970, GFI=.937, RMSEA=.071 (%90 CI =.070-.073), SRMR=.06). The factor loadings of the scale according to CFA are presented in Table 3.

Table 2. *Factor loadings of the scale according to exploratory factor analysis (EFA)*

	1	2	3		4	5	6	7	8	9	10
F1					**F4**						
A1.20	.730			A4.2	.885						
A1.9	.704			A4.3	.854						
A1.18	.696			A4.1	.488						
A1.19	.689					**F5**					
A1.24	.683			A5.9		.782					
A1.14	.681			A5.8		.775					
A1.8	.667			A5.11		.771					
A1.6	.660			A5.7		.762					
A1.11	.657			A5.4		.738					
A1.10	.650			A5.3		.713					
A1.13	.645			A5.6		.704					
A1.21	.639			A5.5		.702					
A1.27	.629			A5.10		.690					
A1.17	.587			A5.12		.677					
A1.28	.573			A5.1		.614					
A1.15	.562			A5.2		.613					
A1.26	.505						**F6**				
A1.7	.497			A6.9			.708				
A1.5	.495			A6.10			.701				
A1.12	.491			A6.13			.696				
A1.2	.473			A6.11			.694				
A1.25	.444			A6.14			.649				
		F2		A6.8			.619				
A2.18		.731		A6.6			.607				
A2.19		.726		A6.3			.573				
A2.21		.714		A6.4			.544				
A2.20		.702		A6.7			.544				
A2.8		.694		A6.5			.531				
A2.14		.684		A6.1			.522				
A2.27		.676		A6.12			.513				
A2.28		.659		A6.2			.497				
A2.9		.651						**F7**			
A2.6		.649		A7.1				.471			
A2.15		.638		A7.3				.408			
A2.13		.628		A7.2				.374			
A2.7		.626							**F8**		
A2.5		.621		A8.2					.828		
A2.17		.619		A8.3					.798		
A2.10		.619		A8.1					.795		
A2.11		.607								**F9**	
A2.26		.607		A9.3						.851	
A2.25		.605		A9.1						.841	
A2.24		.545		A9.2						.635	
A2.1		.532									**F10**
A2.2		.527		A10.1							.872
A2.22		.488		A10.3							.782
A2.12		.487		A10.2							.631
A2.16		.433									
A2.4		.430									
A2.23		.420									
A2.3		.330									
			F3								
A3.2			.847								
A3.1			.815								
A3.3			.694								
A3.6			.618								
A3.4			.484								
A3.5			.381								

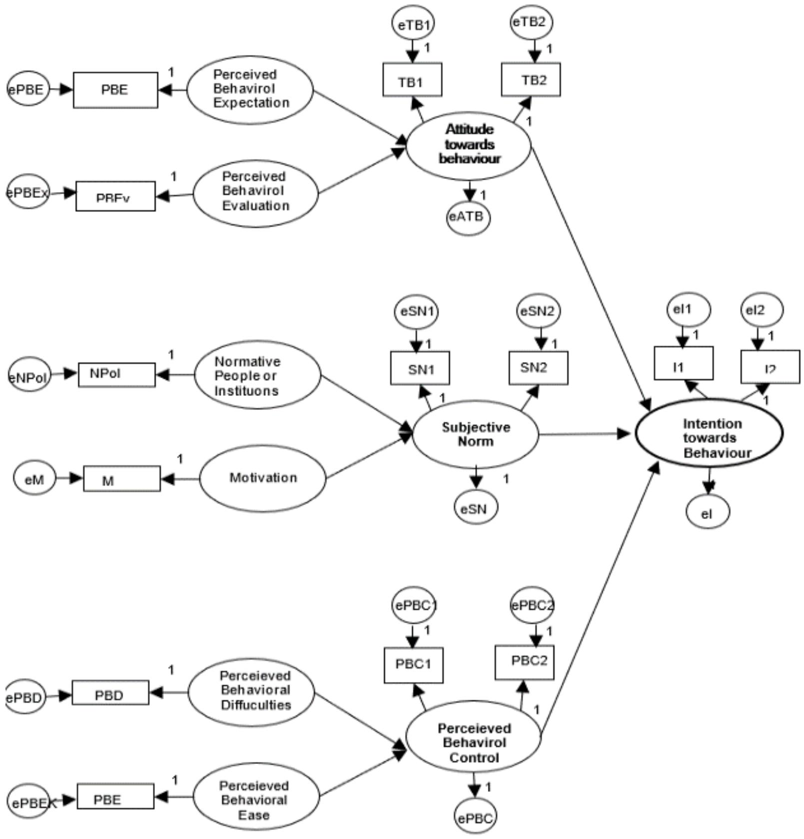
Table 3. *Factor loadings of the scale according to confirmatory factor analysis (CFA)*

	1	2	3		4	5	6	7	8	9	10
	F1				**F4**						
A1.2	.731			A4.1	.873						
A1.5	.813			A4.2	.812						
A1.6	.858			A4.3	.892						
A1.7	.828					**F5**					
A1.8	.781			A5.1		.730					
A1.9	.806			A5.2		.461					
A1.10	.826			A5.3		.797					
A1.11	.868			A5.4		.748					
A1.12	.764			A5.5		.563					
A1.13	.819			A5.6		.727					
A1.14	.849			A5.7		.687					
A1.15	.784			A5.8		.748					
A1.17	.819			A5.9		.689					
A1.18	.853			A5.10		.659					
A1.19	.852			A5.11		.547					
A1.20	.879			A5.12		.685					
A1.21	.838						**F6**				
A1.24	.806			A6.1			.743				
A1.25	.778			A6.2			.783				
A1.26	.807			A6.3			.770				
A1.27	.807			A6.4			.885				
A1.28	793			A6.5			.898				
		F2		A6.6			.899				
A2.1		.781		A6.7			.867				
A2.2		.741		A6.8			.880				
A2.3		.665		A6.9			.900				
A2.4		.733		A6.10			.916				
A2.5		.850		A6.11			.903				
A2.6		.873		A6.12			.879				
A2.7		.859		A6.13			.887				
A2.8		.802		A6.14			.901				
A2.9		.853						**F7**			
A2.10		.789		A7.1				.908			
A2.11		.827		A7.2				.934			
A2.12		.761		A7.3				.825			
A2.13		.774							**F8**		
A2.14		.787		A8.1					.878		
A2.15		.737		A8.2					.798		
A2.16		.751		A8.3					.798		
A2.17		.860								**F9**	
A2.18		.859		A9.1						.758	
A2.19		.802		A9.2						.907	
A2.20		.797		A9.3						.790	
A2.21		.817									**F10**
A2.22		.662		A10.1							.765
A2.23		.615		A10.2							.491
A2.24		.687		A10.3							.723
A2.25		.778									
A2.26		.752									
A2.27		.785									
A2.28		.808									
			F3								
A3.1			.597								
A3.2			.530								
A3.3			.660								
A3.4			.777								
A3.5			.844								
A3.6			.783								

2.4. Data Analysis

The data obtained via data collection tool were analyzed using the AMOS 23 program to model the relationships (Arbuckle, 2014). A 7-point Likert scale ranging from “definitely not” to “yes, definitely” was used. SEM for the TPB is presented in Figure 2.

Figure 2. *SEM for the TPB.*



3. RESULTS

Before examining the assumptions of the model, it was checked whether the categorical and continuous variables in the dataset were within the acceptable limits. In this regard, the frequencies of the categorical variables and the minimum and maximum value ranges of the continuous variables were examined, and no values outside the expected range were found. Missing value examinations were carried out, and no missing data were identified. According to the normal distribution curve, Z-values outside the limits of ±3 are considered outliers (Stevens, 2009). In the study, the Z-values were calculated for all scores, and 7 observations were removed based on this criterion, considering the overall sample size. The skewness value of the variables was -.29, and the kurtosis value was -.167. To meet the normality assumption, the skewness and kurtosis values must remain within the ±2 limits (Tabachnick & Fidell, 2013). A sample size of more than 200 is generally considered sufficient for SEM (Kline, 2011). As a result of the preliminary analysis, 341 students were included in the study, satisfying the sample size requirement for SEM analysis. In this context, the assessment of assumptions related to the measurement tools was completed, and the model testing was initiated.

Fit indices were considered to evaluate model fit (χ^2 =1257.409, df=552, χ^2/df= 2.278, p< .01, CFI=.91, TLI/NNFI=.90, GFI=.821, RMSEA=.061 (%90 CI=.057-.066), SRMR=.05). The goodness-of-fit statistics indicated that the data fit the SEM (Kline, 2011; Jöreskog & Sörbom, 1993). The factor loadings of all items were above .64. The instrument constructs and items were presented in Table 4.

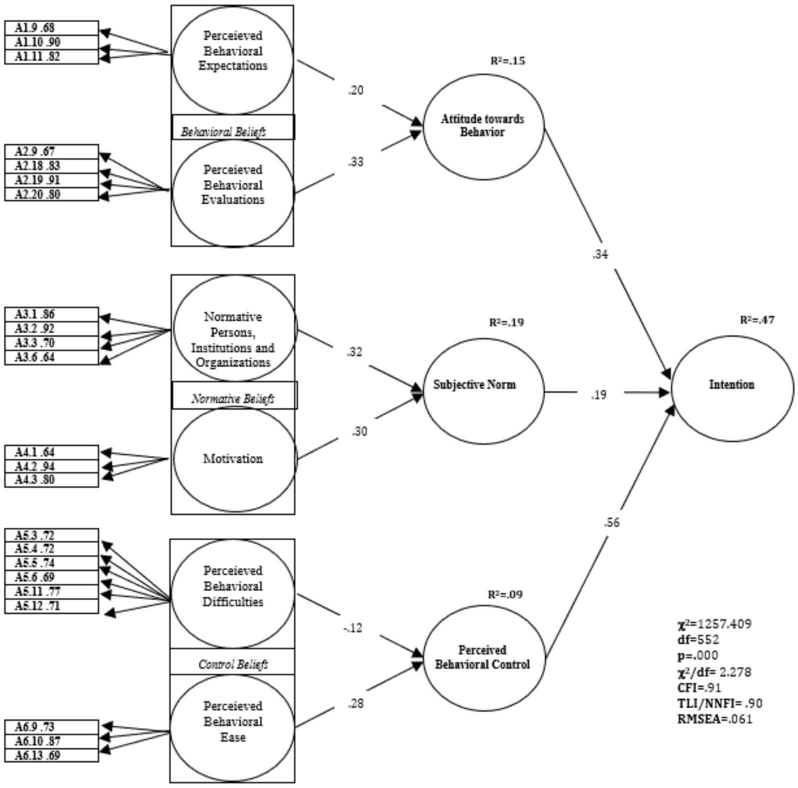
Table 4. *Instrument constructs and items.*

Construct/ Beliefs	Items	Factor loading
A1. Perceived Behavioral Expectations	A1.9. Students develop scientific thinking skills by using AR & VR activities.	.68
	A1.10. Students learn the characteristics of scientific knowledge by using AR & VR activities.	.90
	A1.11. Students improve science process skills by using AR & VR activities.	.82
A2. Perceived Behavioral Evaluations	A2.9. Students' scientific thinking skills development is important by using AR & VR activities.	.67
	A2.18. Students' problem-solving skills development is important by using AR & VR activities.	.83
	A2.19. Students' argument-making skills development is important by using AR & VR activities.	.91
	A2.20. Students' reasoning skills development is important by using AR & VR activities.	.80
A3. Normative Persons, Institutions and Organizations	A3.1. Ministry of National Education	.86
	A3.2. School management	.92
	A3.3. Other science education teachers	.70
	A3.6. Education inspectors	.64
A4. Motivation	A4.1. I am generally ready to do the expectations of people and institutions I value.	.64
	A4.2. I am generally ready to do the expectations of people I value.	.94
	A4.3. I am generally ready to do the expectations of institutions I value.	.80
A5. Perceived Behavioral Difficulties	A5.3. It is difficult due to time limitations for gaining course objectives.	.72
	A5.4. It is difficult since I do not design AR & VR activities.	.72
	A5.5. It is difficult because the number of students is high in the class.	.74
	A5.6. It is difficult because students are not ready to take control of their own learning.	.69
	A5.11. It is difficult because students don't have skills to design AR & VR activities.	.77
	A5.12. It is difficult because the content of course and AR & VR activities are not appropriate.	.71
A6. Perceived Behavioral Ease	A6.9. It is easy because I can guide students to design AR & VR activities.	.73
	A6.10. It is easy because I can provide classroom management during AR & VR activities.	.87
	A6.13. It is easy because students have skills to design AR & VR activities.	.69

The SEM based on the TPB is presented in Figure 3. As shown in the model, the regression equation is as follows:

Behavioral Intention = (Attitude toward behavior * .34) + (Subjective norm * .19) + (Perceived behavioral control * .56)

Figure 3. *SEM based on TPB.*



Standardized regression weight coefficients are presented in Figure 3. The three factors—attitude toward behavior, subjective norm, and perceived behavioral control—explained 47% of the total variance. The R^2 value was calculated as .15 for attitude toward behavior, .19 for subjective norm, and .09 for perceived behavioral control. Hypothesis testing results are presented in Table 5. All hypotheses were supported.

Table 5. *Hypothesis testing results*

Hypothesis	Path	Path coefficient	Result
H1	ATB→BI	$.34^{***}$	Supported
H2	SN→ BI	$.19^{***}$	Supported
H3	PBC→BI	$.56^{***}$	Supported

*** p<.001

4. DISCUSSION

This study applied the Theory of Planned Behavior (TPB) to understand preservice teachers' behavioral intentions to use AR and VR applications as educational tools. A significant gender imbalance exists within the sample, which may affect the representativeness of the results and limit the generalizability of the findings across gender groups. Therefore, the results should be interpreted with this limitation in mind. The findings provide strong empirical support for TPB as an appropriate theoretical framework, consistent with prior research (Ajzen, 1985; Ajzen, 1991; Erten, 2000; Karademir & Erten, 2013; Erten & Köseoğlu, 2022). The results of the study confirm the utility of TPB as a framework for understanding preservice teachers' intention to use AR and VR applications as educational tools. The findings shed light on the factors and related beliefs infleuncing the behavior of using AR and VR activities in educational settings.

The SEM results demonstrated a good fit to the data, indicating that the relationships hypothesized by TPB are consistent with the observed data. SEM analyses confirmed that "Attitude toward Behavior," "Subjective Norm," and "Perceived Behavioral Control" collectively explained 47% of the variance in behavioral intention. According to common standards in educational psychology, explaining nearly half of the variance reflects a moderate to strong predictive power of the model.

However, the R^2 values for individual predictors were relatively low:

- Subjective Norm ($R^2 = .19$),
- Attitude toward Behavior ($R^2 = .15$), and
- Perceived Behavioral Control ($R^2 = .09$).

These low R^2 values may be attributed to the reduction in item numbers during model validation to achieve better fit indices, which potentially decreased the explanatory power of each construct individually. This aligns with the well-known trade-offs in SEM between parsimony and model completeness (Hair et al., 2010).

In terms of path coefficients, following Ajzen and Fishbein (1980)'s interpretation (.0–.3 weak; .3–.5 moderate; .5+ strong regression):

- The path from Attitude toward Behavior → Behavioral Intention was moderate.
- The path from Subjective Norm → Behavioral Intention was weak.
- The path from Perceived Behavioral Control → Behavioral Intention was strong.

These results highlight the particularly crucial role of perceived behavioral control in shaping preservice teachers' intentions. In TPB, perceived behavioral control reflects the perceived ease or difficulty of performing the behavior, suggesting that preservice teachers' confidence in their ability to use AR and VR is a key driver of their intention. Thus, interventions aiming to increase actual control over AR/VR integration—through training, resource availability, and institutional support—are likely enhance behavioral intention.

By facilitating immersive learning experiences that are captivating, memorable, and productive for students, AR and VR technologies have the potential to revolutionize education (Zhang *et al.,* 2022). While VR may bring academic subjects to life by offering students new insights and perspectives, AR can be utilized to display instructional text and lesson-specific content overlaid on a user's real-world environment (Guray & Kismet, 2023). Studies suggest that AR and VR are more effective learning tools than traditional methods because they allow students to act rather than merely observe and experience situations that would not be possible otherwise (Chan *et al.,* 2022). Additionally, AR/VR technology may help students stay engaged in lectures while studying from home (Solmaz *et al.,* 2021). There are similar findings in the literature that align with the results of this study. Karacan and Polat (2022) investiagated pre-service teachers' behavioral intention to use AR and VR applications as educational tools. their results indicated that favorable perceived behavioral control was associated with positive intention to use AR and VR applications, with direct and positive effects. They also reported preservice teachers' views on the disadvantages and limitations of AR technology in teaching practices and learning. Similarly, Anderson and Maninger (2007) found that personal attitudes and abilities significantly explained preservice teachers' behavioral intentions to use software in their future classrooms, which is consistent with the TPB.

Mikropoulos (2022) concluded that preservice teachers have a favorable attitude toward using AR and VR applications as educational tools and hold a positive regarding their integration into educational settings. Moreover, they are likely to demonstrate positive behavioral intentions to use AR and VR applications despite being aware of the challenges and obstacles related to their integration. Similarly, positive attitudes and perceptions of perceived usefulness are significant predictors of preservice teachers' intentions to use educational technologies (Sadaf *et al.,* 2012). Additionally, perceived usefulness, perceived ease of use and computer attitudes were found to be important predictors of both Malaysian and Singaporean preservice teachers' behavioral intentions to use educational technology (Teo *et al.,* 2008). To sum up, attitude and perceived usefulness were important predictors of pre-service teachers' intention to use AR and VR applications as educational tools in their future teaching. The integration of AR and VR applications in pre-service teachers' classrooms help their future middle school students develop technology-related skills.

Even though the statistical impact of perceived behavioral control on behavioral intention is high according to theory, statistically significant effects were also found for the other two factors: subjective norm and attitude toward behavior. Our findings indicated that subjective norm, or social pressure, does not play a crucial role in shaping behavioral intention. However, preservice teachers still believe that institutions such as Ministry of National Education, school management and individuals such as other science education teachers and education inspectors are important. Erten (2000) stated that the key concept is to strengthen the effectiveness of teachers' attitudes. Moreover, in TPB, subjective norm is defined as the extent to which teachers believe that important people think they should use AR and VR applications as educational tools. Subjective norm is similar to social influence of behavior —the more social expectation there is, the stronger the behavioral intention becomes. Social conditions and infleunce facilitate the acceptance of AR and VR applications by pre-service teachers (Koutromanos & Mikropoulos, 2021). Similarly, perceived behavioral control was found to have the highest influence on preservice teachers' intentions, whereas social influence and anxiety had a low direct effect on behavioral intention to use technology (Baydas & Göktaş, 2017). However, these factors were found to have a high indirect effect on intention through other variables such as perceived behavioral control and efficacy, and perceived ease-of-use. In the present study, the effect of the subjective norm on behavioral intention was lower than the other variables, as social influence was not considered highly important by the pre-service teachers.

5. CONCLUSION

"Attitudes", "subjective norms", "perceived behavioral control" and "behavioral intentions" of preservice teachers regarding the use of AR and VR as educational tools will have a considerable influence on the effective adoption and use of these technologies in educational settings. Accordingly, it is important to understand the factors related to their behavioral intentions and the relationships between these factors and behavioral intentions. A key findin of this study is that attitudes towards behavior, subjective norm and perceived behavioral control collectively explain a large proportion of variance in preservice teachers' intention to use AR and VR applications as educational tools. As preservice teachers' confidence in their ability to use AR and VR applications effectively in educational settings increases, so do their behavioral intentions to adopt these tools. To a moderate extent, teachers' behavioral intentions also increase when their perceptions of others' expectations —as a form of social influence—are heightened. Academic contributions to AR and VR in education include studies on how effectively these technologies can enhance student learning outcomes, as well as the development of innovative teaching strategies and course materials that leverage the features of AR and VR (Solmaz *et al.,* 2021). Additionally, researchers are exploring the use of AR and VR in special education, STEM education, and language teaching (Chan *et al.,* 2022). Numerous studies have examined the comparative effectiveness of VR, Ar, hands-on learning, and/or traditional instruction. Findings indicate that students' learning outcomes are equally affected by hands-on activities conducted in virtual and real-world settings (Bansal *et al.,* 2022).

These findings imply that although preservice teachers perceived both benefits and limitations were of AR and VR, their behavioral intentions to use these technologies as educational tools were mainly influenced by perceived behavioral control. Hence, educational policy and teacher education programs have an important role to play in preparing preservice teachers to navigate both the advantages and limitations of AR and VR integration. To this extent, teacher training programs should engage preservice teachers in first-hand experiences with AR and VR technologies to improve their attitudes and beliefs regarding the effectiveness of these tools and to strengthen their confidence in using them. In addition, preservice teachers should participate in AR- and VR-embedded activities to reflect on their beliefs about the use of these technologies in education and the reasons behind those beliefs. It's becoming evident that learning has been significantly transformed by AR and VR technology. These tools not only increase engagement and interaction within the learning environment but also enhance information retention and support the development of practical skills. While VR has opened up new opportunities for exploration and engagement in virtual settings, AR, with its capacity to superimpose digital information onto the physical world, has enriched traditional instructional resources. Looking forward, there are both opportunities and challenges in the integration of AR and VR in education. The primary challenges include the high cost of these technologies, the need for a robust technological infrastructure, and the development of meaningful and engaging content. Nevertheless, many opportunities lie ahead. AR and VR have the potential to fundamentally transform traditional teaching approaches, address diverse learning demands, and offer personalized learning experiences. It is likely that the future of AR and VR in education will focus on enhancing user experience, increasing accessibility, and achieving seamless integration into educational programs.

6. SUGGESTIONS

In the study, according to the TPB model, pre-service teachers' perceived behavioral control, subjective norms and attitudes explained 47% of their behavioral intentions. In future studies, it is recommended to expand the model by identifying additional variables that may explain behavioral intention. In addition, the data collected from preservice teachers is a limitation, as it is based on self-assessment. Future studies should incorporate not only scales and questionnaires but also qualitative data such as observations and interviews. Behavioral intentions of preservice teachers can be examined more thoroughly through mixed-method research supported by qualitative data. In this study, perceived behavioral control and attitude were found to be statistically more related to behavioral intention. The subjective norm variable, representing social influence, was less associated with behavioral intention compared to the other variables in the model. When interpreting the findings, it is important to consider that these relationships may vary in studies conducted across different cultural contexts. This study was carried out with preservice teachers enrolled in various state universities in Turkey; therefore, personal variables may be affected by cultural values and beliefs. The study is also limited in terms of its duration and focus, which should be considered in further studies.

Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. This research study complies with research publishing ethics. The scientific and legal responsibility for manuscripts published in IJATE belongs to the authors. **Ethics Committee Number**: Bartin University, Social and Human Sciences Ethics Committee, 14.03.2024, 3-1.

Contribution of Authors

All authors: Investigation, Resources, Visualization, Software, Formal Analysis, Methodology, Supervision, Validation and Writing-original draft.

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REFERENCES

Ajzen, I. (1985). From intentions to actions: A theory of planned Behavior. In J. Kuhl & J. Beckman (Eds.), *Action-control: From cognition to Behavior*. Heidelberg, Germany: Springer.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*, 179-211. https://doi.org/10.1016/0749-5978(91)90020-T

Ajzen, I. (2002). Perceived behavioral control, self-efficacy, locus of control, and the theory of planned behavior. *Journal of Applied Social Psychology, 32*(4), 665-683. https://doi.org/10.1111/j.1559-1816.2002.tb00236.x

Ajzen, I., & Fishbein, M. (1977). Attitude-behavior relations: A theoretical analysis and review of empirical research. *Psychological Bulletin, 84*(5), 888-918. https://doi.org/10.1037/0033-2909.84.5.888

Ajzen, I. (2012). The theory of planned behavior. In P.A.M. Lange, A.W. Kruglanski, & E.T. Higgins (Eds.), *Handbook of theories of social psychology*. Sage.

Ajzen, I., & Fishbein, M. (1980). *Understanding Attitudes and Predicting Social Behavior*. Prentice-Hall.

Ajzen, I., & Madden, T.J. (1986). Prediction of goal-directed behavior: Attitudes, intentions, and perceived behavioral control. *Journal of Experimental Social Psychology, 22*, 453-474. https://doi.org/10.1016/0022-1031(86)90045-4

Ajzen, I., & Fishbein, M. (2008). Scaling and testing multiplicative combinations in the expectancy-value model of attitudes. *Journal of Applied Social Psychology, 33*(9), 2222-2247. https://doi.org/10.1111/j.1559-1816.2008.00389.x

Alalwan, N., Cheng, L., Al-Samarraie, H., Yousef, R., Alzahrani, A. I., & Sarsam, S.M. (2020). Challenges and prospects of virtual reality and augmented reality utilization among primary school teachers: A developing country perspective. *Studies in Educational Evaluation, 66*(2), 100-876. https://doi.org/10.1016/j.stueduc.2020.100876

Anderson, S.E., & Maninger, R.M. (2007). Preservice teachers' abilities, beliefs, and intentions regarding technology integration. *Journal of Educational Computing Research, 37*(2), 51-172. https://doi.org/10.2190/H1M8-562W-18J1-634P

Arbuckle, J.L. (2014). *IBM SPSS Amos 23 User's Guide*. IBM.

Armitage, C.J., & Conner, M. (1999). The theory of planned behavior: Assessment of predictive validity and 'perceived control. *British Journal of Social Psychology, 38*(1), 35-54. https://doi.org/10.1348/014466699164022

Bansal G., Rajgopal K., Chamola V., Xiong Z., & Niyato D. (2022). Healthcare in metaverse: A survey on current metaverse applications in healthcare. *IEEE Access, 10*, 119914-119946.

Baydas, O., & Goktas, Y. (2017). A model for preservice teachers' intentions to use ICT in future lessons. *Interactive Learning Environments, 25*(7), 930-945. https://doi.org/10.1080/10494820.2016.1232277

Bonetti, F., Warnaby, G., & Quinn, L. (2018). *Augmented reality and virtual reality in physical and online retailing: A review, synthesis and research agenda.* In: Jung, T., Tom Dieck, M. (Eds.), *Augmented Reality and Virtual Reality. Progress in IS*. Springer, Cham.

Can, H., & Higde, E. (2022). Pre-Service Teachers' Intentions to Implement STEM Activities. *Shanlax International Journal of Education, 10*(7), 164-178. https://doi.org/10.34293/education.v10iS1-Aug.4956

Cennamo, K., & Kalk, D. (2019). *Real world instructional design: An iterative approach to designing learning experiences.* Routledge.

Chan V.S., Haron H.N.H., Isham M.I.B.M., & Mohamed F.B. (2022). VR and AR virtual welding for psychomotor skills: A systematic review. *Multimedia Tools and Applications, 81*(9), 12459-12493.

Coban, M., Bolat, Y.I., & Goksu, I. (2022). The potential of immersive virtual reality to enhance learning: A meta-analysis. *Educational Research Review*, 100-452. https://doi.org/10.1016/j.edurev.2022.100452

Demitriadou, E., Stavroulia, K.E., & Lanitis, A. (2020). Comparative evaluation of virtual and augmented reality for teaching mathematics in primary education. *Education and Information Technologies, 25*, 381-401. https://doi.org/10.1007/s10639-019-09973-5

Dutt, S., Sharma, R., Suyal, P., & Thapliyal, M. (2022, December 16-17). *An investigative study of long-term implication of extended reality applications in educational pursuits for learning-disabled population: a recommendation approach*. 11th International Conference on System Modeling & Advancement in Research Trends, Moradabad, India. https://dx.doi.org/10.1109/SMART55829.2022.10046886

Erten, S., & Koseoglu, P. (2022). A review of studies in the field of educational sciences within the context of theory of planned behavior. *Journal of Turkish Science Education, 19*(2), 389-402. https://doi.org/10.36681/tused.2022.127

Erten, S. (2000). *Empirische untersuchungen zu bedingungen der umwelterziehung ein interkultureller vergleich auf der grundlage der theorie des geplanten verhaltens*. [*Empirical studies on the conditions of environmental education: an intercultural comparison based on the theory of planned behavior*]. Tectum Verlag. Marburg. Deutschland.

Fishbein, M., & Ajzen, I. (1975). *Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research.* Addison-Wesley.

Fishbein, M., & Ajzen, I. (2010). *Predicting and Changing Behavior: The Reasoned Action Approach*. Psychology Press.

Fundi, M., Sanusi, I.T., Oyelere, S.S., & Ayere, M. (2024). Advancing AI education: Assessing kenyan in-service teachers' preparedness for integrating artificial intelligence in competence-based curriculum. *Computers in Human Behavior Reports, 14*, 1-10. https://doi.org/10.1016/j.chbr.2024.100412

Guray T.S., & Kismet B. (2023). Applicability of a digitalization model based on augmented reality for building construction education in architecture. *Construction Innovation, 23*(1), 193–212.

Hair Jr, J.F., Hult, G.T.M., Ringle, C.M., Sarstedt, M., Danks, N.P., Ray, S., ... & Ray, S. (2021). An introduction to structural equation modeling. *Partial least squares structural equation modeling (PLS-SEM) using R: a workbook*, 1-29.

Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: A systematic literature review of quantitative learning outcomes and experimental design. Journal of Computers in Education, 8(1), 1-32. https://doi.org/10.1007/s40692-020-00169-2

Huang, H.M., Rauch, U., & Liaw, S.S. (2010). Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach. *Computers & Education, 55*(3), 1171-1182. https://doi.org/10.1016/j.compedu.2010.05.014

Johnson, A.M., Jacovina, M.E., Russell, D. G. & Soto, C.M. (2016). *Challenges and solutions when using technologies in the classroom*. In ByScott A. Crossley, Danielle S., & McNamara (Eds.), *Adaptive educational technologies for literacy instruction*, Routledge.

Jöreskog, K., & Sörbom, D. (1993). *LISREL 8: Structural equation modeling with the SIMPLIS command language*. Scientific Software International.

Karacan, C.G. & Polat, M. (2022). *Pre-service language teachers' development of augmented reality applications: A qualitative inquiry into their intention of augmented reality use*. In Zou, B., & Barr, D. (Eds.), *Emerging concepts in technology-enhanced language teaching and learning*. IGI Global.

Karademir, E., & Erten, S. (2013). Determining the factors that affect the objectives of pre-service science teachers to perform outdoor science activities. *International Journal of Education in Mathematics, Science and Technology, 1*(4), 270-293.

Kenna, J.L., & Potter, S. (2018). Experiencing the world from inside the classroom: Using virtual field trips to enhance social studies instruction. *The Social Studies, 109*(5), 265-275. https://doi.org/10.1080/00377996.2018.1515719

Kline, R.B. (2011). *Principles and Practice of Structural Equation Modeling*. The Guidford Press.

Koutromanos, G., & Mikropoulos, T.A. (2021, May 17-June 10). *Mobile augmented reality applications in teaching: A proposed technology acceptance model*. [Paper presentation]. 7th International Conference of the Immersive Learning Research Network, Eureka, USA. https://doi.org/10.23919/iLRN52045.2021.9459343

Kraus, M., Custovic I., & Kaufmann W. (2021). Struct-mrt: Immersive learning and teaching of design and verification in structural civil engineering using mixed reality. arXiv preprint arXiv:2109.09489. https://doi.org/10.13140/RG.2.2.27661.46563

Lee, C.K., & Shea, M. (2020). Exploring the use of virtual reality by pre-service elementary teachers for teaching science in the elementary classroom. *Journal of Research on Technology in Education, 52*(2), 163-177. https://doi.org/10.1080/15391523.2020.1726234

Lin, Y.J., & Wang, H.C. (2021). Using virtual reality to facilitate learners' creative self-efficacy and intrinsic motivation in an EFL classroom. *Education and Information Technologies, 26*(4), 4487-4505. https://doi.org/10.1007/s10639-021-10472-9

Makridakis, S. (2017). The forthcoming Artificial Intelligence (AI) revolution: Its impact on society and firms. *Futures, 90*, 46-60. https://doi.org/10.1016/j.futures.2017.03.006

Mazman, A.S.G. (2019). Does it matter being innovative: Teachers' technology acceptance. *Education and Information Technologies, 24*(6), 3415-3432. https://doi.org/10.1007/s10639-019-09933-z

Mikropoulos, T.A., Delimitros, M., & Koutromanos, G. (2022). *Investigating the mobile augmented reality acceptance model with pre-service teachers.* [Paper presentation]. 8th International Conference of the Immersive Learning Research Network, Vienna, Austria. https://doi.org/10.23919/iLRN55037.2022.9815972

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *Ieice Transactions on Information and Systems, 77*(12), 1321-1329.

Osipenko, L., & Guseva, V. (2022). Place and role of visualization among the modern methodological tools of higher education process. *Education and Information Technologies*, 1-14. https://doi.org/10.1007/s10639-022-11310-2

Papanastasiou, G., Drigas, A., Skianis, C., Lytras, M., & Papanastasiou, E. (2019). Virtual and augmented reality effects on K-12, higher and tertiary education students' twenty-first century skills. *Virtual Reality, 23*, 425-436. https://doi.org/10.1007/s10055-018-0363-2

Roopa, D., Prabha, R., & Senthil, G.A. (2021). Revolutionizing education system with interactive augmented reality for quality education. *Materials Today: Proceedings, 46*, 3860-3863. https://doi.org/10.1016/j.matpr.2021.02.294

Sadaf, A., Newby, T.J., & Ertmer, P.A. (2012). Exploring factors that predict preservice teachers' intentions to use web 2.0 technologies using decomposed theory of planned behavior. *Journal of Research on Technology in Education, 45*(2), 171-196. https://doi.org/10.1080/15391523.2012.10782602

Santos, J.M., & Castro, R.D. (2021). Technological Pedagogical content knowledge (TPACK) in action: Application of learning in the classroom by pre-service teachers (PST). *Social Sciences & Humanities Open, 3*(1), 100-110. https://doi.org/10.1016/j.ssaho.2021.100110

Schepman, A., & Rodway, P. (2020). Initial validation of the general attitudes towards Artificial Intelligence Scale. *Computers in Human Behavior Reports, 1*, 1-13. https://doi.org/10.1016/j.chbr.2020.100014

Scherer, R.F. (1988). Dimensionality of Coping: Factor Stability Using the Ways of Coping Questionnaire, *Psychological Report*, *62*(3), 763-770.

Schifter, D.E., & Ajzen, I. (1985). Intention, perceived control, and weight loss: An application of the theory of planned Behavior. *Journal of Personality and Social Psychology, 49*(3), 843-851. https://doi.org/10.1037/0022-3514.49.3.843

Schott, C., & Marshall, S. (2018). Virtual reality and situated experiential education: A conceptualization and exploratory trial. *Journal of Computer Assisted Learning, 34*(6), 843-852. https://doi.org/10.1111/jcal.12293

Sermet, Y., & Demir, I. (2020). *Virtual and augmented reality applications for environmental science education and training.* In Daniela, L. (Eds.), *New Perspectives on Virtual and Augmented Reality*, Routledge.

Shankar, A.U., Tewari, V., Rahman, M., Mishra, A., & Bajaj, K.K. (2023). Impact of virtual reality (VR) and augmented reality (AR) in education. *Tuijin Jishu/Journal of Propulsion Technology, 44*(4), 1310-1318. https://doi.org/10.52783/tjjpt.v44.i4.1014

Stevens, J.P. (2009). Applied multivariate statistics for the social sciences (5th Ed.). United States: Taylor and Francis Group, LLC.

Solmaz S., Dominguez Alfaro J.L., Santos P., Van Puyvelde P., & Van Gerven T. (2021). A practical development of engineering simulation-assisted educational AR environments. *Education for Chemical Engineers, 35*, 81-93.

Tabachnick, B.G., & Fidell, L.S. (2013). *Using multivariate statistics* (6th Ed.). Pearson.

Teo, T., Luan, W.S., & Sing, C.C. (2008). A cross-cultural examination of the intention to use technology between Singaporean and Malaysian pre-service teachers: An application of the Technology Acceptance Model (TAM). *Journal of Educational Technology & Society, 11*(4), 265-280.

Tomaschko, M. (2020). *Exploiting the potential of mobile learning in mathematics education* [Doctoral dissertation]. Universität Linz.

Wagner, T. (2010). *The Global Achievement Gap: Why Even Our Best Schools Don't Teach The New Survival Skills Our Children Need-And What We Can Do About It*. Basic Books.

Wu, H.K., Lee, S.W.Y., Chang, H.Y., & Liang, J.C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education, 62*, 41-49. https://doi.org/10.1016/j.compedu.2012.10.024

Zhang C., Wang X., Fang S., & Shi X. (2022). Construction and application of VR-AR teaching system in coal-based energy education. *Sustainability, 14*(23), 16033. https://doi.org/10.3390/su142316033