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Augmented Reality Applications in Education and Examining Key Factors Affecting the Users' Behaviors

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Abstract: Augmented Reality (AR) is increasingly influential in education. AR technology allows users to learn and practice in a simulated environment that enables repetition, correction, and failure without risk. The present study evaluated users' attitudes towards using AR for learning complex tasks. The users are asked to interact with an AR Piling (ARP) application that shows various steps of a construction process. A set of selected practitioners and students used the application, and the evaluation involved various participants of different genders and backgrounds. A questionnaire was designed and data was collected through an online survey based on the Technology Acceptance Model (TAM). The model is modified considering education practices and adjusted to an AR app for learning purposes. The novelty of the model lies in various constructs such as technical quality, social influence, perceived immersion, learning, and perceived enjoyment. 200 responses were obtained and used for evaluating the proposed model. The attitude toward using AR and the perceived usefulness of AR were the two factors that determined the participants' behavioral intention to use ARP. Respondents showed a high level of acceptance for AR. In education and higher learning contexts, the findings of this study contribute to a deeper understanding of how AR is accepted in complex learning environments. The study allows us to extend the TAM by examining how AR technology can be applied to teaching in universities and unpack the ways in which gender influences learning through AR application.

Keywords: Augmented Reality; technology adoption; TAM; learning process

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1. Introduction

The limitations of traditional approaches to teaching and learning theories through lectures and textbooks often serves to complicate the learning process [1]. In technical applications especially, higher education involves learning practical concepts that are often complex, abstract, and intangible [2]. This is especially the case for students from equity backgrounds and international students [3]. COVID-19 has further limited opportunities for students to engage beyond textbook learning practice through limiting access to construction projects [4]. New technologies may offer a solution to these challenges, while increasing student motivation and interest and improving attitudes towards learning [5,6]. AR (Augmented Reality) and VR (Virtual Reality) are some of the most quickly developing and widely adopted of these new learning and teaching technologies [7,8]. AR brings physical and digital information together in real-time through different technological formats such as smartphones and tablets, enabling users to interact with virtual images superimposed onto the real world [9]. VR is a medium made up of computer simulations in which feedback is altered or augmented based on the user's actions, creating the feeling of being physically present or mentally immersed in the simulation [10]. In academic contexts, AR especially offers a variety of possibilities that are attractive to learners, teachers, and institutions [11,12]. Huang, et al. [13], Alkhattabi [14] asserted that utilizing AR in the learning process could offer positive pedagogical contributions, learner outcomes, and interaction. Providing interaction opportunities, promoting ubiquitous learning, creating the safe artificial scenarios for users, making the information more comprehensible by enriching it with reality, using training activities, promoting self-learning, increasing the level of engagement, and applying it to a variety of disciplines and educational levels, are the most important strength of integrating AR into education. These technologies are especially valuable for their ability to give users the opportunity to test scenarios that would be dangerous or difficult to accomplish in real life, in a safe environment [15]. In light of these possible benefits, the [16] use of VR and AR in academic environments has grown significantly in recent years as educators, organizations and researchers employ new technologies in efforts to add a new dimension to the classroom environment [17–19]. Reference [20] predicts the VR, AR, and Mixed Reality (MR) market will grow by over USD 30 billion by 2030. Reference [21] predicted that 14 million American employees will probably utilize AR smart glasses on a daily basis by 2025.

Despite their application in numerous fields, especially in learning and education, the implications, impacts, and effects of using AR technologies are contentious [3]. Several studies indicate AR technologies especially offer benefits for student engagement and learning performance. Wang, et al. [22] developed a VR-enhanced BIM immersive system for quantity surveying practice and education based on two main components; non-immersive systems (desktop VR) and immersive systems (head-mounted displays). Through VR-BIM, users gained a deeper understanding of mechanical, electrical, and plumbing (MEP) systems. As a result of the developed VR-BIM system, quantity surveying jobs could be performed more efficiently after trial use, and students were able to grasp and apply concepts better than those in textbooks. In a study involving 396 university students, Cabero-Almenara, et al. [23] used material created in AR as an enhancement to traditional notes or books. Information was presented in video, audio, and multimedia resources through QR codes. Students were found to be willing to use AR in their future education, and perceptions of enjoyment on the part of the students and their intentions to use AR affected their academic performance. Wojciechowski and Cellary [24] assessed learning attitudes among secondary school students in an AR environment where teachers authored interactive educational scenarios using an e-learning system. This research used interface style and perceived enjoyment as external constructs of TAM. A significant relationship was found between perceived ease of use and interface style and perceived usefulness, whereas these two constructs did not have any association with perceived enjoyment. Luo and Mojica Cabico [25] evaluated the effect of AR-based learning tools on learning performance among 40 undergraduate construction engineering students. This study used AR to show various types of bridge structures. Mobile AR tools were found to be more effective than conventional learning methods by improving academic performance. Gavish, et al. [26] investigated the use of AR systems as possible training platforms to support employees in procedural maintenance and repair tasks. Aromaa, et al. [27] used a mobile handheld AR system for technicians in routine preventive field service. The results indicated the potential benefits of using this technology particularly in performing the first maintenance task. Martín-Gutiérrez, et al. [28] investigated the use of AR for promoting collaborative and autonomous learning in higher education. The results indicated that AR could achieve a connection between the laboratory practices and theoretical explanations. Furthermore, students emphasized the convenience and usefulness of this technology.

While the above studies report positive impacts on satisfaction and student engagement, few academic studies have substantiated AR's educational benefits [29]. Some studies suggest that AR technology can help students grasp complex concepts in educational settings [30,31]. However, several studies have also identified weaknesses in the use of AR as an educational aid. The literature mentions several weaknesses associated with integrating AR, including difficulty for students to use [32], high time consumption [26], the distraction of students' attention [33], and incompatibility with large group instruction [34]. Lin, et al. [35], found that students may find AR learning difficult because of technical issues and complicated interfaces. It has also been found that individuals and organizations do not widely use AR due to a lack of adequate empirical analysis [36]. Some studies that do show positive outcomes of AR technology in the classroom also suggest a confluence of factors including teacher skill and involvement are also critical to successful AR learning and teaching. Tzima, Styliaras and Bassounas [2] examined teachers' opinions on AR training and diffusion, and the feasibility of AR applications developed by students and teachers in school. Several factors, including the teacher's personality and their desire for collaboration, were found to contribute to the feasibility of AR application development. Much of the research that supports AR technology as a learning tool is also limited to Western countries and the developed world. Few empirical studies discuss factors the use of AR technologies for education in non-Western countries or in developing countries [37]. Chiang, Yang and Hwang [33] developed location-based AR environment with a guiding mechanism to guide students to share knowledge in inquiry learning activities among 57 fourth-grade students in Northern Taiwan. Students were divided into experimental and control groups. The experimental group learned with AR and the control group learned with conventional in-class mobile learning. This study found that AR-based inquiry learning activities are more engaging for students than conventional inquiry-based mobile learning activities.

Some studies of VR/AR have considered the impact of gender on AR use, finding that gender has an influence on the adoption of AR technology [38,39]. Abed [40] found that gender has a statistically significant effect on whether persons intend to adopt AR. However, in AR-related science studies, the learning experience is seldom discussed, and determining if technology assists students' learning is important. According to a systematic review undertaken by [41] there is a need to understand how AR is used in learning and study its impacts, especially on science learning. Essentially, current research on the effects of AR technologies on learning is divided regarding AR's efficacy, and limited in its considerations of non-Western contexts and gender. Further research is needed to examine the impacts of AR application on learning process [37,42]. This study aims to provide a deeper consideration of the factors that contribute to successfully implementing AR and VR technology in a learning context in a non-Western country with considerations of gender.

This study has the following specific objectives:

1. To identify the factors affecting AR acceptance;
2. To examine participants' behavioral intentions to use AR;
3. To examine the impact of practitioners' and students' gender on their acquisition of knowledge;
4. To examine the differences of opinion between students and practitioners in utilizing AR as a new method in the learning procedure.

2. Theoretical Framework

2.1. Educational AR Applications

Technologies and tools are introduced in this section which shows how new technologies, such as AR, can be used in construction education. For practical construction courses, these tools and applications were developed. There are five interactive modules that Sepasgozar [4] introduces, which can be utilized in a variety of courses including digital construction, risk management, practice-based courses, and construction informatics. These modules have the following names: a Piling AR (ARP), Virtual Tunnel Boring Machine (VTBM), Group Wiki Project (GWiP), Digital Twin (DT), and Interactive Construction Tour 360 (iCRT 360). The ARP was selected for this research. Through ARP, users can view and interact with all steps in a safe environment. This module allows the user to explore the model section-by-section Figure 1.

Figure 1. Implementation of the ARP by a selected user in an open area.

2.2. Theoretical Research Framework

The Technology Acceptance Model (TAM) has been demonstrated in various research studies to be a robust and valid model that can be used in any technological environment to clarify behavioral intention. In TAM, the individual's attitudes and intentions are assessed to predict their behavior according to the psychological theory of "reasoned action" [43]. However, it also displays "perceived self-efficacy" [44]. According to perceived self-efficacy, people believe that they are capable of producing certain levels of performance that can have a significant influence on their lives. Those who possess a strong sense of self-efficacy develop a greater interest in participation in their activities. Their involvement in their interests and activities will become stronger as a result. Individual attitudes toward new technology are most strongly influenced by perceived usefulness and ease of use, according to the model [43]. An individual's attitude towards a particular technology relies on these constructs, and their behavioral intention toward that technology is influenced by them. This is determined by different external constructs, such as gender, technical quality, perceived enjoyment, social influence, perceived immersion, type of user, and degree of training [45].

Figure 2 illustrates the model for this research study. The TAM model with gender, technical quality, and perceived enjoyment as external constructs was analyzed through a structural equation model for further confirmation [46]. Cho, et al. [47] and Gerhard, et al. [48] have expressed the importance of the perceived immersion as an external construct and [49,50] expressed the social influence. Because these two constructs have been used in many studies [51], they have been added to the model of this research.

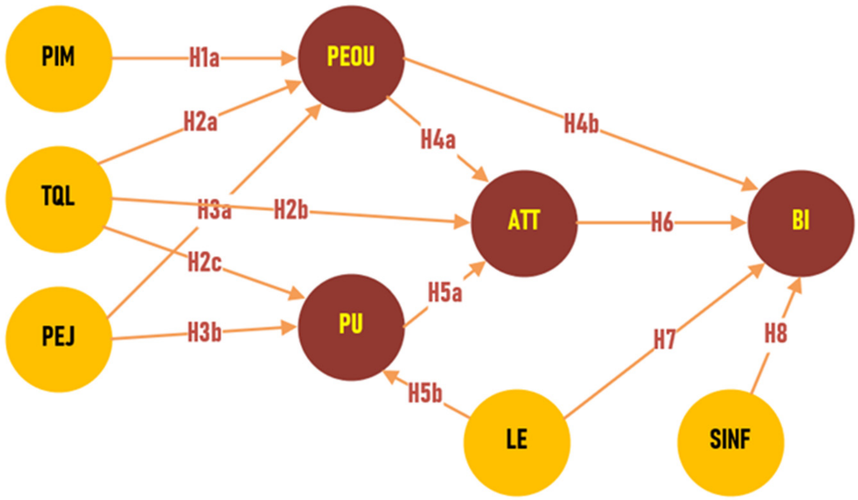

Figure 2. The novel AR adoption model, including 12 hypothetical paths and nine key variables.

Perceived immersion (PIM)

A key element of PIM is the possibility of engaging users and enhancing their AR experience. Immersive engineers' and students' learning styles promote practical, valuable, and meaningful experiences. In order to make virtual tools effective, immersion is one of the primary factors. Engineers' and students' motivation to know more about the required equipment may be heightened by an immersive learning environment. When users are immersed in AR environments, they have been shown to improve their learning motivation and attitudes [52,53].

H1a. *The perceived immersion can positively and significantly affect the perceived ease of use.*

Technical quality (TQL)

TQL means the degree to which an individual perception about the technical functioning of AR. The technical functioning of AR technology can be very effective in using this technology in educational environments for engineers and students. In terms of technical ability, this technology should be able to satisfy the needs of its users to the extent they desire so that this technology can be used as a suitable alternative to traditional methods. Technology performance and efficiency can be adversely affected by poor technical quality [23,54].

H2a. *Technical quality can positively and significantly affect the perceived ease of use.*

H2b. *Technical quality can positively and significantly affect attitude.*

H2c. *Technical quality can positively and significantly affect the perceived usefulness.*

Perceived enjoyment (PEJ)

PEJ means the degree of enjoyment that each individual gets in using AR. The greater the amount of entertainment and enjoyment while using AR technology, the more it can lead to the use of this technology. A learning environment that is fun and entertaining can add to the enthusiasm of engineers and students in using this technology and also, according to research, can lead to the easy use of AR technology for users. Studies indicated that user technology acceptance is strongly influenced by perceived enjoyment [23,55].

H3a. *The perceived enjoyment can positively and significantly affect the perceived ease of use.*

H3b. *The perceived enjoyment can positively and significantly affect the perceived usefulness.*

Perceived ease of use (PEOU)

PEOU refers to personal expectations of how easy it will be to use AR. The better the perceived ease of use of AR, users are more likely to accept it. Technology is more likely to be accepted by the public and implemented if it is family-friendly, user-friendly, and identical to the user's living standards. When users perceive that the AR will be easy to use and can assist them in working effectively, they are more likely to accept it [23,43,56].

H4a. *The perceived ease of use can positively and significantly affect the attitude.*

H4b. *The perceived ease of use can positively and significantly affect behavioral intention.*

Perceived usefulness (PU)

It is the amount users expect AR to improve their learning that is measured by PU. This term describes engineers' and students' expectations of how much the virtual course enabled them to know better. It reflects how much the engineers and students believe a virtual system is helpful. AR technology should be perceived as being useful for learners to achieve desirable learning results. A well-designed learning environment helps users to perceive that the technology is useful and will make them more likely to use the technology. The emotional attributes and enjoyment of virtual learning have been linked to this concept by some scholars [43,57,58].

H5a. *The perceived usefulness can positively and significantly affect the attitude.*

H5b. *The learning can positively and significantly affect the perceived usefulness.*

Attitude (ATT)

ATT means the degree to which a person's attitude is positively or negatively inclined towards the usage of AR. There was a great deal of influence on technology acceptance through attitude, and users may still use technology if they perceive it to be useful and/or easy to use. The positive or negative attitudes of students and engineers in using AR technology in the educational environment can be effective. As if they use this new technology with a positive attitude, it will lead to more productivity and more information [23,59].

H6. *The attitude can positively and significantly affect behavioral intention.*

Learning (LE)

LE means using AR affects users' observational and operational learning productivity. User conduct and developments can be changed over to virtual conditions. Additionally, comparing the effectiveness of AR as a teaching tool to traditional methods to gauge the level of learning users achieve. AR provide users with a virtual environment in which they can experience real-world scenarios. This experience can affect the level of operational and observational learning productivity. Furthermore, in comparison to traditional teaching methods such as lectures, presentations, and books, this technology can allow students to gain a deeper understanding of topics [60,61].

H7. *Learning can positively and significantly affect the behavioral intention.*

Social influence (SINF)

SINF refers to how much an individual believes others should use AR, based on the kinds of essentials they perceive. In using new technologies such as AR, individuals are always looking to find out if other individuals who work or study with them are using this technology or not. Usually, most students and engineers are eager to use this technology when they see that it is used by others around them. By doing this, users first ensure the effective capabilities of the new technology and then use it [49,50].

H8. *Social influence can positively and significantly affect behavioral intention.*

3. Method

3.1. Design and Instruments

This study employs a quantitative, constituting a questionnaire and online survey to collect data concerning the respondent's demographic characteristics and each construct of TAM. The questionnaires were sent randomly to 300 practitioners and students through social media as a URL that allowed them to access the survey directly. In the first section of the questionnaire, participants watched a nearly two-minute video of the "ARP" module works discussed in the previous sections. In the next step, the application was available for participants to use at their own discretion. Once the participant watched the ARP video, the questionnaire was made available to them, including two background and main sections. Participants then answered two questions about their job status and gender. In the second section, respondents answered questions regarding each proposed technology acceptance model factor. The questionnaire comprised 22 items, which collected information on the different constructs. Four questions were adapted from the perceived usefulness established by [23]. Two questions were adapted from the perceived ease of use established by [23,43]. Two questions were adjusted for each of the remaining constructs for perceived enjoyment found by [23], technical quality established by [23], social influence established by [49,50], perceived immersion established by [48], attitude set by [23,59], and behavioral intention to use established by [23,59]. Four questions were used for the learning construct. The final answer for each factor in the survey was administered on a 5-point Likert Scale. Several statistical analyses such as, descriptive analysis, Cronbach's Alpha, discriminant validity, Path coefficients with *t*-value, a permutation test and *p*-value, PLS-MGA analysis, and Welch-Satterthwaite analysis, were used to develop and validate the proposed acceptance model. The proposed analysis methods have been used according to other studies in this filed such as, [52,62,63].

3.2. Participants

The research was conducted among civil engineering and architectural students enrolled in master's degrees, studying in either of the two universities in Isfahan, Iran. Practitioners whose names are registered in the list of members of Isfahan engineering also participated in this research. In previous studies examining VR and AR adoption, a sample size as large as this was observed [64–66]. Data was collected from July–September 2021, and then was prepared for analysis after the closing of the survey. From the 300 questionnaires distributed for the survey, 200 respondents (around a 67% response rate) were received and found to be valid for data analysis. The total number of respondents included 62% female and 38% male, with 70 practitioners and 130 students (Table 1).

Table 1. Data profile and background questions.

Background Information		Frequency	Percentage
Job Status	Practitioners	70	35%
	Students	130	65%
	Total	200	100%
Gender	Female	124	62%
	Male	76	38%
	Total	200	100%

4. Data Analysis and Results

4.1. Proposed Model

We investigated the adoption of AR technology in education as the primary purpose of this study. This assessment was made in order to assess the factors that influence AR technology adoption. The secondary objectives of this study have been examined separately. According to Table 2, every question has been analysed descriptively.

Table 2. Statistical analysis of sample including t and p values, outer loadings and VIF.

ID	Measures/Questions	Original Sample (O)	t Values	p Values	Loading	Outer VIF
ATT1	Learning is made more interesting by using AR	0.933	99.848	0.000	0.933	2.021
ATT2	Overall, I like the idea of using AR	0.916	55.686	0.000	0.916	2.021
BI1	It would be great if I had the opportunity to use AR in the future	0.930	73.365	0.000	0.930	2.223
BI2	I intend to begin using AR	0.936	109.496	0.000	0.936	2.223
LE1	Using AR as a teaching tool, enhances the level of learning productivity	0.879	40.201	0.000	0.879	2.673
LE2	After using AR, the efficiency of learning and teaching goes up	0.909	55.127	0.000	0.909	3.161
LE3	I feel that training with the help of AR is very different from the traditional methods (with the help of books, lectures, etc.) in the amount of learning	0.663	7.869	0.000	0.663	1.409
LE4	In general, training with the use of AR is more effective and better than traditional methods	0.911	58.496	0.000	0.911	3.194
PEJ1	I enjoyed using the AR technology	0.921	71.910	0.000	0.921	1.881
PEJ2	I believe AR allows learning while playing	0.915	55.769	0.000	0.915	1.881
PEOU1	I believe that AR are easy to use	0.896	33.747	0.000	0.896	1.467
PEOU2	It does not take a lot of mental effort to interact with AR	0.872	32.387	0.000	0.872	1.467
PIM1	My senses were utterly engaged during the experience of AR	0.863	20.453	0.000	0.863	1.487
PIM2	How compelling was your sense of being presented in AR	0.908	39.393	0.000	0.908	1.487
PU1	I believe that AR are useful to reflect the actual context of construction sites	0.827	26.473	0.000	0.827	1.984
PU2	My learning and performance in this course will be enhanced by using AR	0.887	40.919	0.000	0.887	3.425
PU3	I will be able to better comprehend certain concepts if AR is used during the class	0.827	19.743	0.000	0.827	1.915
PU4	For learning, AR is generally useful to me	0.892	42.655	0.000	0.892	3.435
SINF1	People who are important to me would think using AR as a good idea	0.865	29.857	0.000	0.865	1.482
SINF2	People who influence education think that I should use AR	0.906	65.715	0.000	0.906	1.482
TQL1	The functioning of the AR that we have presented was good enough	0.833	21.843	0.000	0.833	1.335
TQL2	Your overall rating would be based on the AR's technical functionality as a new learning method	0.896	67.853	0.000	0.896	1.335

Note to table: VIF: variance inflation factor; the analysis is based on five scale of Likert from Strongly Disagree (1) to Strongly Agree (5).

In order to measure the reliability, Cronbach's alpha was analysed and it proves the internal consistency of questions which shows convergent validity. Table 3 shows that Cronbach's alpha is varied from 0.587 to 0.721 and are greater than 0.6 [67,68]. The following equation was used for composite reliability (CR) analysis [69]:

$$\boldsymbol{CR} = (\sum \lambda_i{}^2)/[(\sum \lambda_i{}^2) + (\sum \mathbf{Var}(\varepsilon_i))]$$

where, λ_i is the standardized loading, and $\text{Var}(\varepsilon_i)$ is the variance of the error. Table 3 also shows that the CR coefficients are greater than 0.6 and ranging from 0.783 to 0.808 [69]. It also shows that AVE values are acceptable since they are greater than 0.5 and are between from 0.418 to 0.553 [69].

Table 3. Construct reliability and validity outcomes.

	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)	Q^2 (=1-SSE/SSO)	R Squared	R Squared Adjusted
ATT	0.831	0.838	0.922	0.855	0.690	0.817	0.815
BI	0.852	0.853	0.931	0.871	0.606	0.728	0.723
LE	0.864	0.889	0.909	0.717			
PEJ	0.813	0.813	0.914	0.842			
PEOU	0.721	0.726	0.877	0.782	0.109	0.171	0.158
PIM	0.728	0.746	0.879	0.785			
PU	0.881	0.883	0.918	0.738	0.569	0.802	0.799
SINF	0.726	0.741	0.879	0.784			
TQL	0.667	0.689	0.856	0.748			

Note: Q^2: prediction relevance, SSE: the sum of the squares of prediction errors; SSO: the sum of the squares of observations.

Fornell and Larcker [69] suggested some criteria for testing the discriminant validity. Table 4 shows that there is correlation between measures and they are ranging from 0.408 to 1.000.

Table 4. Discriminant validity of measures (acceptable based on Fornell-Larcker criteria).

	ATT	BI	LE	PEJ	PEOU	PIM	PU	SINF	TQL
ATT	0.925								
BI	0.762	0.933							
LE	0.777	0.801	0.847						
PEJ	0.705	0.803	0.728	0.918					
PEOU	0.266	0.395	0.391	0.249	0.884				
PIM	0.653	0.752	0.725	0.671	0.375	0.886			
PU	0.904	0.807	0.835	0.736	0.314	0.667	0.859		
SINF	0.643	0.728	0.736	0.672	0.318	0.721	0.682	0.885	
TQL	0.761	0.755	0.740	0.673	0.358	0.637	0.825	0.643	0.865

Table 5 shows the results of students' t-test statistics and tests. The value of f^2 is between 0.036 and 4.070 for supported relationships. Figure 3 shows the outcome of testing the model structure, including the proposed relationships among variables.

Table 5. Summary of hypotheses testing outcomes and the statistical values for verification of VTAM.

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	p Values	Inner VIF	f^2	Hypothesis Acceptability
ATT -> BI	0.317	0.330	0.099	3.216	0.001	2.614	0.142	Supported
LE -> BI	0.334	0.320	0.094	3.569	0.000	3.535	0.116	Supported
LE -> PU	0.418	0.420	0.072	5.822	0.000	2.807	0.315	Supported
PEJ -> PEOU	−0.117	−0.119	0.094	1.250	0.211	2.234	0.007	Not supported
PEJ -> PU	0.156	0.159	0.052	2.996	0.003	2.324	0.053	Supported
PEOU -> ATT	−0.020	−0.017	0.032	0.612	0.541	1.109	0.002	Not supported
PEOU -> BI	0.102	0.102	0.040	2.551	0.011	1.190	0.032	Supported
PIM -> PEOU	0.295	0.302	0.102	2.900	0.004	2.054	0.051	Supported
PU -> ATT	0.910	0.908	0.019	46.689	0.000	1.109	4.070	Supported
SINF -> BI	0.245	0.245	0.065	3.803	0.000	2.255	0.098	Supported
TQL -> PEOU	0.249	0.246	0.106	2.354	0.019	2.065	0.036	Supported
TQL -> PU	0.410	0.405	0.080	5.096	0.000	2.418	0.352	Supported

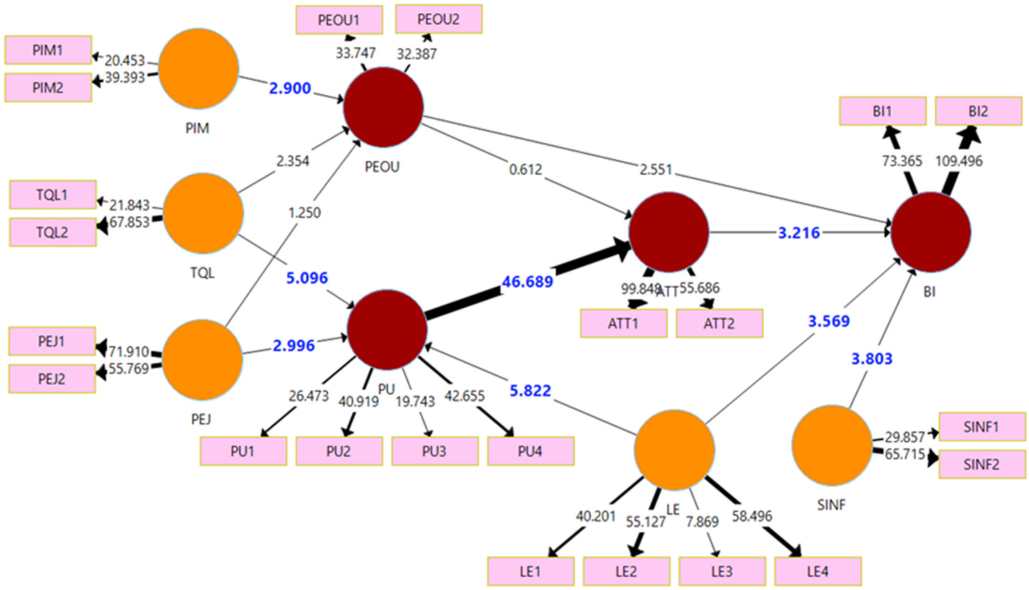

Figure 3. The verified VR model including, including the relative path coefficient values and *t*-values.

The result of the structural modelling statistical analyses, including a two-tailed t-test from the bootstrap, are shown in Table 5. The PLS computation shows that INT, MOV, and PRF have 0.525, 0.230, and 0.369 of the total variances explained in their respective variables, which are all greater than 2%. Table 5 also shows that inner VIF is acceptable since they are varied from 1.000 to 1.619 and are lower than 5.

4.2. Comparing Various Participants

The PMGA and Welch-Satterthwaite were computed on the AR adoption model to explore any significant difference in modelling based on the gender or profession of participants. The computation evaluated the AR adoption model for these groups of participants: female—male participants and practitioners—students' participants.

As a prerequisite for conducting the multi-group evaluation, an invariance test using the permutation approach was utilized [70]. The range of permutation *p*-values for each path of gender groups is from 0.011 to 0.874 and for the profession, group varies from 0.006 to 0.873. The permutation analyses show that the difference among the selected two groups of participants for most paths is non-significant (p-value > 0.05). The MGA was applied to each path to cross-validate this result, and the proposed model's 12 pathways coefficient was computed. As a result, 5000 permutations were run using a two-tailed test at a significance level of 0.05. Tables 6–8 show the outcomes of the permutation, PMGA, and the Welch-Satterthwaite tests.

The PLS-MGA results of *p*-values show that there are significant differences between female and male participants on the PU -> ATT path, where $p = 0.003$. The Welch-Satterthwaite results validate this outcome by $t = 2.862$ and $p = 0.003$ for the same path which has been computed for the gender group. The PLS-MGA results of *p*-values show significant differences between practitioners and students on the PIM -> PEOU and TQL -> PEOU paths, where $p = 0.027$ and 0.015, respectively (refer to Table 7). The Welch-Satterthwaite results validate this outcome by $t = 2.352$ and 2.622 and $p = 0.021$ and 0.010, respectively (refer to Table 8). These values were computed for the same path based on the profession of participants.

Table 7 shows the PMGA results where the *p*-value for all other paths in both gender and profession group of participants vary from 0.105 to 0.834. The PMGA reveals that there were no significant differences between the rest of the paths in these groups. The computations show that the results of PMGA and the Welch-Satterthwaite tests are consistent in terms of the significance of differences among various group of participants.

Table 6. Permutation test results and *p*-values for participants with different gender and profession.

Path	H	Path Coefficients Permutation Mean Difference (Female-Male)	Permutation *p*-Values	Path Coefficients Permutation Mean Difference (Practitioners-Students)	Permutation *p*-Values
PIM -> PEOU	H1a	−0.015	0.112	0.015	0.024
TQL -> PEOU	H2a	0.011	0.688	−0.002	0.006
TQL -> PU	H2c	−0.001	0.761	−0.008	0.050
PEJ -> PEOU	H3a	0.001	0.567	−0.004	0.492
PEJ -> PU	H3b	−0.001	0.592	0.006	0.188
PEOU -> ATT	H4a	−0.002	0.149	0.002	0.324
PEOU -> BI	H4b	0.001	0.381	0.001	0.577
PU -> ATT	H5a	0.000	0.002	−0.002	0.129
ATT -> BI	H6	−0.011	0.478	0.013	0.873
LE -> PU	H5b	0.003	0.555	0.000	0.176
LE -> BI	H7	0.007	0.799	−0.012	0.764
SINF -> BI	H8	0.004	0.110	−0.004	0.148

Table 7. PLS-MGA results of *p*-values for participants with different gender and profession.

Path	H	Path Coefficients-Diff (Female-Male)	*p*-Value Original 1-Tailed (Female vs. Male)	*p*-Value New (Female vs. Male)	Path Coefficients-Diff (Practitioners-Students)	*p*-Value Original 1-Tailed (Practitioners vs. Students)	*p*-Value New (Practitioners vs. Students)
PIM -> PEOU	H1a	−0.339	0.876	0.249	0.485	0.013	0.027
TQL -> PEOU	H2a	0.093	0.312	0.624	−0.576	0.992	0.015
TQL -> PU	H2c	−0.066	0.660	0.681	0.311	0.052	0.105
PEJ -> PEOU	H3a	0.106	0.341	0.682	−0.136	0.737	0.526
PEJ -> PU	H3b	0.061	0.304	0.608	−0.154	0.853	0.294
PEOU -> ATT	H4a	0.096	0.078	0.156	0.068	0.156	0.312
PEOU -> BI	H4b	0.073	0.192	0.384	−0.049	0.737	0.527
PU -> ATT	H5a	−0.128	0.999	0.003	0.063	0.057	0.114
ATT -> BI	H6	0.160	0.161	0.322	−0.032	0.644	0.711
LE -> PU	H5b	0.105	0.281	0.563	−0.214	0.950	0.101
LE -> BI	H7	−0.057	0.640	0.721	−0.059	0.583	0.834
SINF -> BI	H8	−0.222	0.947	0.107	0.212	0.058	0.117

Table 8. Welch-Satterthwaite results of *p*-values for participants with different gender and profession.

Path	H	Path Coefficients-Diff (Female-Male)	*t*-Value (|Female vs. Male|)	*p*-Value (Female vs. Male)	Path Coefficients-Diff (Practitioners-Students)	*t*-Value (|Practitioners vs. Students|)	*p*-Value (Practitioners vs. Students)
PIM -> PEOU	H1a	−0.339	1.160	0.250	0.485	2.352	0.021
TQL -> PEOU	H2a	0.093	0.457	0.649	−0.576	2.622	0.010
TQL -> PU	H2c	−0.066	0.406	0.686	0.311	1.783	0.079
PEJ -> PEOU	H3a	0.106	0.426	0.671	−0.136	0.617	0.539
PEJ -> PU	H3b	0.061	0.542	0.589	−0.154	1.067	0.290
PEOU -> ATT	H4a	0.096	1.423	0.158	0.068	1.015	0.313
PEOU -> BI	H4b	0.073	0.869	0.387	−0.049	0.570	0.570
PU -> ATT	H5a	−0.128	2.862	0.005	0.063	1.496	0.138
ATT -> BI	H6	0.160	0.850	0.398	−0.032	0.141	0.888
LE -> PU	H5b	0.105	0.606	0.546	−0.214	1.597	0.115
LE -> BI	H7	−0.057	0.330	0.742	−0.059	0.280	0.781
SINF -> BI	H8	−0.222	1.662	0.100	0.212	1.624	0.108

5. Discussion

This study investigated the factors that contribute to learning from AR tools and the factors that hinder learning performance when using AR among civil engineering and architectural students enrolled in master's degrees in Isfahan, Iran. The study tested an acceptance model for learning in AR, the Technology Acceptance Model (TAM), based on previous studies that have identified the relevant variables for describing the procedure of learning in AR [45,46]. The TAM was selected due to its power as a model for analyzing user behavior in researching emerging technologies' adoption. In addition to its conceptual validity and statistical significance, this model confirms earlier analyses and conclusions for adopting AR systems in other countries.

Regarding this study's hypothesis (H3a), perceived enjoyment was not found to be correlated to perceived ease of use. This indicates that participants were more concerned with the enjoyability of the AR technology, and less concerned with ease-of-use. This leads us to suggest that unlike [24], AR users may be more concerned with factors such as better technical quality and usefulness rather than the entertainment value of AR technologies. Unlike other research [24,71], reported enjoyment was not found to be influential in the acceptance of VR technology. A moderate difference in acceptance of AR technology across participants' genders and occupations was found, unlike other works carried out with different technologies [23,38]. This study also revealed significant differences between female and male participants on the PU -> ATT path, despite the findings of [38]. In terms of perceived usefulness and attitude towards implementing AR, this study finds that gender does play a significant role. One of this study's central findings is that AR will be successfully accepted and adopted in the learning process if the factors identified including, perceived immersion, technical quality, perceived usefulness, perceived ease of use, social influence, learning, and attitude, are considered. These results support earlier findings by [28,46,66,71] about the high acceptance of AR in education. This study's results also differ somewhat from the TAM model assumption, which states that users' acceptance of this technology is strongly related to its technical quality.

Participants' professions as users of AR technology were also addressed in this study. The research showed that practitioners and students on the PIM -> PEOU and TQL -> PEOU pathways differ significantly, where $p = 0.027$ and 0.015, respectively. This might be because students and practitioners have different perspectives on how AR technology can be used and applied in the learning process. No significant differences were found between other paths in these groups. Concerning H2c, H3b, and H5b hypotheses, the perceived usefulness of VR can be significantly positively influenced by technical quality, perceived enjoyment, and learning. Unlike other studies [23,71,72], this study found that attitudes toward AR were not positively influenced by perceived ease of use (H4a). According to H5a, perceived usefulness positively and significantly affects attitudes toward using AR technology. Similar to other studies [23,24,72], attitudes toward using AR positively affects behavioral intention (H6). As a result of using Pearson's correlation coefficient, the results are consistent with those of other authors regarding the significance of the model [46]. Therefore, the TAM model is sufficient to understand the degree of acceptance and future intention. In summary, this study's findings suggest that AR can be used in learning procedures as a training and learning tool to be used in the future. In line with other studies [2,23,72], the acceptance and implementation of AR was more possible under certain conditions. In this research, it was found that factors such as technical quality, the usefulness of AR, and its lack of complexity, have a significant effect on raising the attitude towards the use of this technology. Similar to other studies [22], the use of AR leads to better understanding and learning of users. However, in this regard, teacher-training [23], using effective educational materials [72], and the proper use of AR technology [71], the possible deviation and the creation of educational intervention were prevented. The results of this research are consistent with other studies in the field of education and learning through AR [24,28,71].

Education institutions, learners, system developers, managers, marketers, and educators can benefit significantly from this study's findings to understand AR technology dynamics, which will improve the acceptance of AR in learning settings. This study found that the following factors are crucial to predicting behaviors associated with the adoption of AR technology in the learning environment: attitude, perceived immersion, the perceived ease of use, technical quality, perceived usefulness, perceived enjoyment, social influence, and learning. Any institution wishing to use AR in the classroom should consider characteristics related to these factors. AR features are an important variable to emphasize using AR to enhance learning. The developers of AR apps need to pay more attention to the app immersion feature and 3D view, which provide a much better visualization to users than 2D images of the content. Especially in this research, students may find it difficult to fully visualize the spatial elements of construction piling process, despite the lecture notes and images that provide explanations and two-dimensional views of the process. Learners with high levels of presence have greater intrinsic motivation and ease of use, which directly impacts their behavioral intention to use AR for learning.

While this research provides a theoretical model that can potentially be a good predictor of immersive interactive tools, the model needs further testing by various groups of participants from different regions to provide more generalizable, and predictive results. Another limitation of this research is related to the method conducted in this study. In this research, only a sample of existing AR applications has been used, and the volunteers that participated in the research may be those that liked the technology while some others who did not like it, never answer the questionnaire. These gaps can be resolved by other researchers in the future. Future studies need to discuss the performance expectance of the immersive tools and find out how practitioners can use them for other tasks such as building façade, excavation, pouring concrete, using tower cranes, and other job site activities. Research should be conducted in different directions in the future, in order to overcome some of the limitations of the present study. In the future, a wider range of academic institutions and universities should be included in future studies. Studying mobile-based technologies was carried out in the current study; future studies should examine computer-based technologies. Research on the acceptance and adoption of AR has been limited within educational contexts and across subject domains. Future empirical tests should consider ongoing studies under varying educational contexts and subjects.

Finally, this research indicates that AR/VR developers should pay attention ease of use, that a high degree of ease of use and usefulness is crucial for AR users' learning. This is related to their attitude, perceived enjoyment, social influence, and learning construct, leading to their intention to use AR. For instance, designing an AR tool that provides meaningful and detailed information about the construction process can lead to high usefulness and usability in AR tools. As mentioned, AR adoption in learning is influence by the social influence factor. Most students and practitioners mentioned that if other students and colleagues use AR technology, their motivation to use this technology will increase, which may be because individuals are looking for the usability and usefulness of this technology, not just to use new technology. Similar to other study results [71], with the advancement of technology, the number of people who use this technology increases; however, paying attention to the quality and details of the AR content (similar to [24]) from system developers can help use AR technology in the learning process.

6. Conclusions

This study aimed to examine the adoption of AR among students in universities and practitioners to improve technology's effectiveness in the learning process. In all, 200 students and practitioners in architecture and civil engineering courses in Isfahan, Iran, using the ARP construction module were surveyed for their opinions on factors that impact AR adoption. The study tested the Technology Acceptance Model (TAM) to assess attitudes and likely uptake of AR. The results suggest that perceived immersion, technical quality, enjoyment, learning, and social influence were external constructs that affect AR adoption in the learning process (research Question 1). All hypotheses were supported except H3a (the perceived enjoyment can positively and significantly affect the perceived ease of use) and H4a (the perceived ease of use can positively and significantly affect the attitude). There was no significant and positive impact on the perceived ease of use and attitude towards utilizing AR in education based on perceptions of enjoyment and ease of use, respectively. Technical quality and perceived usefulness were found to affect participant attitudes towards using AR in the learning process. The results showed that due to the use of ARP Applications, the level of the behavioral intention of users in using AR was high. Significant differences were found between participants' gender and profession in accepting

AR technology. There were significant differences between female and male participants on the PU -> ATT path (by t = 2.862 and p = 0.003). PIM -> PEOU and TQL -> PEOU pathways differed significantly between practitioners and students. The rest of the paths did not differ significantly between these groups. Generally, this research showed that the adoption and acceptance rate of AR technology is high among students and practitioners, consistent with other studies [23,28,71]. AR technology can significantly impact users' learning process and experience. Education institutions, universities, system developers, and marketers can benefit significantly from this study's findings to understand AR technology dynamics, which will enhance the acceptance of AR in education.

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