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The mobile augmented reality acceptance model for teachers and future teachers

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Abstract
This study examines the factors that affect pre-service and in-service teachers' intention to use Mobile Augmented Reality (MAR) in their teaching through the proposed Mobile Augmented Reality Acceptance Model (MARAM). The MARAM builds on the existing Technology Acceptance Model (TAM) to incorporate four other components namely perceived relative advantage, perceived enjoyment, facilitating conditions, and mobile self-efficacy. In addition, this study investigates the validity of the MARAM. Data were collected from 137 pre-service and 169 in-service teachers who completed a questionnaire after having developed their own MAR applications during an undergraduate university course and a training seminar, respectively. Structural Equation Model (SEM) analysis was conducted separately for each group, as well as for both samples together. We also conducted a multi-group analysis to examine differences across the two samples. The results for both samples together (N=306), showed that intention was affected by attitude, perceived usefulness and facilitating conditions. In turn, attitude was affected by perceived enjoyment and perceived usefulness. Perceived usefulness was affected by perceived enjoyment and perceived relative advantage. Perceived ease of use was affected by mobile self-efficacy and facilitating conditions. However, perceived ease of use did not affect perceived usefulness or attitude. A multi-group analysis conducted on the sample of pre-service and in-service teachers produced similar results, with minor differentiations. These results have implications for the use of MAR in research and schools, as well as technology acceptance models in education.

Keywords Technology Acceptance Models · Mobile Augmented reality · Pre-service teachers · In-Service Teachers · Education · Mobile Augmented reality Acceptance Model

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1 Introduction

Augmented Reality (AR) is considered an emerging immersive technology in education and "can be defined as a technology which overlays virtual objects (augmented components) into the real world" (Akçayır & Akçayır, 2017, p. 1). More specifically, in AR, the digital content is 3D aligned with real-world objects with which users interact in real-time (Azuma et al., 2001). Compared to other digital technologies, AR has educational affordances that favorably argue its use in various subjects and fields (e.g., STEM, social sciences). Such AR affordances include a combination of digital and physical objects in a real environment (Dunleavy et al., 2009), first-person view (Koutromanos et al., 2020), the concretization and representation of invisible, complex, and abstract concepts (Akçayır & Akçayır, 2017; Bujak et al., 2013) and the real-time interaction with virtual objects (Azuma, 1997; Zhou et al., 2022). From late 2008, a wealth of research experience has indicated that AR has positive effects on learning (e.g., Chen et al., 2017; Garzón and Acevedo, 2019; Ibáñez and Delgado-Kloos, 2018; Theodoropoulos and Lepouras, 2021), including the development of various skills (Lin et al., 2015), the enhancement of student interest (Arici et al., 2021), motivation (Chang & Hwang, 2018) and engagement (Ibáñez & Delgado-Kloos, 2018), collaborative learning (Garzón et al., 2020) as well as knowledge enrichment (Chang et al., 2022; Ibáñez et al., 2014).

Today, technological advances and smart mobile devices (e.g., smartphones, tablets) in addition to the integration of AR systems into these devices have made the development and availability of next-generation AR applications, books, and games such as PokemonGo (Ruiz-Ariza et al., 2018) readily accessible. Moreover, new authoring Mobile Augmented Reality (MAR) platforms and tools can be developed without requiring users to have programming skills (Atwood-Blaine & Huffman, 2017; Striuk et al., 2018). Teachers and students having access to these resources can now easily create their own MAR learning artefacts and interact with digital objects in various formats (i.e., 3D objects, sound, video, pictures, text, links) anytime and anywhere (e.g., in formal and informal didactic situations). Therefore, this AR which is "generated and rendered with mobile devices in mobile environments, addressing a wide range of application areas" (López-Faican & Jaen, 2020, p. 2), is called Mobile Augmented Reality (MAR).

Despite the multiple MAR applications, platforms and tools, the use of AR in schools remains limited. Previous studies have reported several challenges that hinder the success of AR in teaching and learning, including the lack of technical infrastructure and devices in schools, the limited number of applications for educational purposes (Arici et al., 2021), usability issues and technical problems (Akçayır & Akçayır, 2017), as well as the high cost of devices and applications (Ajit, 2021). However, the success of MAR integration depends not only on the organizational and technical infrastructure in schools but also on the teachers who are willing to implement MAR in their teaching practice. Specifically, research has suggested that pre-service and in-service teachers' beliefs and attitudes towards technology play an important role in the successful acceptance of any digital technologies in education (Teo, 2015). In this context, some AR studies have already examined the acceptance of MAR in teaching and learning by pre-service teachers (e.g., Cabero-Almenara et al., 2019; Nizar et al., 2019; Rahmat and Mohamad, 2021) and in-service teachers (e.g., Ibili et al., 2019; Jang et al., 2021), with most having used in their methodologies specific models and theories from social psychology and information systems fields, such as the Technology Acceptance Model (TAM) (Davis, 1989; Davis et al., 1989) and other modified versions of TAM, as well as the Unified Theory of Acceptance and Use of Technology model (UTAUT) (Venkatesh et al., 2003).

However, aside from the fact that there are relatively few studies on MAR acceptance by pre-service and in-service teachers, they too show certain limitations. Firstly, some acceptance models focus on investigating the acceptance of a particular application for a specific subject (e.g., Geometry, Cardiovascular disease, Geography) (e.g., Ibili et al., 2019; Nizar et al., 2019; Pasalidou & Fachantidis, 2021). Secondly, only a small number of previous studies have evaluated the extent to which the proposed models fit the data collected from their samples (Asiri & El-Aasar, 2022; Jang et al., 2021; Ma et al., 2021). Thirdly, there are models, such as the extended Technology Acceptance Model (eTAM) (Jang et al., 2021), which examine Virtual Reality (VR) and AR together. We believe that, although both these immersive technologies share certain common characteristics and affordances, they also have differences, and therefore, from a methodological point of view, need to be investigated independently. Fourthly, the acceptance models are tested on a sample who used a MAR that had either been developed by the researchers (e.g., Cabero-Almenara et al., 2019; Ibili et al., 2019; Nizar et al., 2019; Rahmat and Mohamad, 2021) or institutions like the Ministry of Education (Jang et al., 2021). Some studies failed to mention whether the sample interacted with the MAR (e.g., Asiri and El-Aasar, 2022), while in others, the sample merely attended a brief seminar or lecture about AR (Ning et al., 2019). Studies in which the sample had the opportunity to create their own AR educational applications, are limited. Fifthly, and most importantly, there is no acceptance model for MAR that can be used both with pre-service teachers and in-service teachers. The study by Ning et al. (2019) used the UTAUT on both samples of educators, however, the second and fourth limitations mentioned above were observed in this study.

To address the above limitations, and to better understand MAR acceptance in schools in the future, we propose a new model called the Model of Augmented Reality Acceptance (MARAM) (Koutromanos & Mikropoulos, 2021; Mikropoulos et al., 2022). The MARAM builds on the existing TAM to incorporate four other components: perceived relative advantage, perceived enjoyment, facilitating conditions, and mobile self-efficacy. More specifically, we consider that for teachers to use Mobile Augmented Reality (MAR) in teaching, they need to believe that it possesses unique advantages over other existing digital technologies. In addition, they need to view MAR as enjoyable in their teaching. Furthermore, they need to feel that the conditions that will facilitate their use of MAR, such as resources, time, and knowledge, are available. Finally, we believe that teachers who perceive self-efficacy in their use of mobile devices will consider MAR easier to use in their teaching practice. The effect of these four additional proposed components is examined on the four existing components of the TAM: intention, attitude, perceived usefulness, and perceived ease of use.

Therefore, this study's aim is twofold. First, to investigate the factors that affect pre-service and in-service teachers' intention to use MAR in their future teaching.

Secondly, to propose a research model to evidence the acceptance of MAR – the MARAM – and to determine whether the MARAM is a valid model to explain the intention of using MAR by two samples (i.e., pre-service, and in-service teachers).

The contribution of the present study on MAR is equally twofold. Firstly, proposing a new acceptance model – the MARAM – allows to further study the factors affecting the acceptance of MAR in education. Secondly, to the best of our knowledge, this study is the first that proposes a new model that investigates and compares the acceptance of MAR in two different samples: in-service and pre-service teachers. It is important to mention that all previous MAR studies used separate acceptance models for these two groups, whereas our study provides a greater understanding into the overall acceptance of MAR by two different target groups through the use of a single model. On the one hand, new empirical insights may help schools formulate an appropriate educational policy to support in-service teachers on the use of MAR in their teaching, and on the other hand, help universities adopt MAR in their curricula to educate and better prepare students aspiring to become teachers on the integration of this new immersive technology in their future classrooms.

The remainder of this article is structured as follows. The next section briefly presents the models and theories of technology acceptance, as well as the existing research that has been conducted on the acceptance of MAR by pre-service and in-service teachers. Thereafter, the proposed MAR acceptance model– the MARAM – is explained and the research hypotheses are presented. The methodology of the study and results of the data analysis follow. The article concludes with a discussion of the results, main conclusions and emerging implications, its limitations and suggestions for future studies.

2 Theoretical framework

Table 1 presents a list of constructs of the most widely used technology acceptance models and theories in education, as well as relevant definitions. We should emphasize that the theoretical basis of several technology acceptance models is founded on the Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1980), and the Theory of Planned Behavior (TPB) (Ajzen, 1985, 1991). According to the TRA, an individual's behavior – for example, his or her decision to use digital technology – depends on the degree of positive intention they possess toward it. An individual's intention, in turn, is affected by two constructs: their attitude toward the behavior and subjective norms. These constructs are formulated by behavioral and normative beliefs respectively. The TRA however, was found to be best suited for behaviors where individuals have complete control (Sheppard et al., 1988). Ajzen (1985, 1991) then developed the TPB to overcome this limitation of the TRA. This new theory develops the existing TRA constructs, by adding the construct of perceived behavioral control, which influences intention and behavior. The TPB therefore relies on control beliefs. In practice, the TPB has been broadly used across various settings and samples in education and is currently considered a substantial theory in attempting to understand human intention and behavior. For example, the TPB was used to investigate pre-service teachers'

Table 1 List of constructs and definitions of the most widely used models and theories in education

Author/s	Model/Theory	Components	Component's Definitions
Ajzen and Fishbein (1980); Fishbein and Ajzen (1975)	Theory of Reasoned Action (TRA)	Attitude toward the behavior	"the individual's positive or negative evaluation of performing the behavior" (Ajzen & Fishbein, 1980, p. 6)
		Subjective norms	"person's perception that most people who are important to him think he should or should not perform the behavior in question" (Fishbein & Ajzen, 1975, p. 302)
		Behavioral beliefs	"beliefs about the likely consequences or other attributes of the behavior" (Ajzen, 2002, p. 665)
		Normative beliefs	"beliefs about the normative expectations of other people" (Ajzen, 2002, p. 665)
Ajzen (1988, 1991)	Theory of Planned Behavior (TPB)	The TRA variables	See above
		Perceived Behavioral control	Adapted from the TRA (see above)
		Behavioral beliefs	Adapted from the TRA (see above)
		Normative beliefs	Adapted from the TRA (see above)
		Control beliefs	"beliefs about the presence of factors that may further or hinder performance of the behavior" (Ajzen, 2002, p. 665)
Davis (1989)	Technology Acceptance Model (TAM)	Attitude toward the behavior	Adapted from the TRA (see above)
		Perceived usefulness	"the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989, p. 320)
		Perceived ease of use	"the degree to which a person believes that using a particular system would be free from effort" (Davis, 1989, p. 320)
Taylor and Todd (1995)	Combined TAM – TPB or The decomposed Theory of Planned Behavior	The variables of TPB and TAM	See above
		Compatibility	Adapted from Innovation Diffusion Theory (IDF), (see below)
		Peer influence	-
		Superior's influence	-
		Self-efficacy	"an individual's self-confidence in his/her ability to perform a behavior" (Taylor & Todd, 1995, p. 150)
		Resource facilitating condition	"the availability of resources needed to engage in a behavior, such as time, money or other specialized resources" (Taylor & Todd, 1995, p. 150)
		Technology facilitating condition	"With respect to IT usage, the facilitating conditions construct provides two dimensions for control beliefs: one relating to resource factors such as time and money and the other relating to technology compatibility issues that may constrain usage" (Taylor & Todd, 1995, p. 152)

Table 1 (continued)

Author/s	Model/Theory	Components	Component's Definitions
Venkatesh and Davis (2000)	TAM 2	Perceived usefulness and Perceived ease of use	Adapted from the TAM (see above)
		Subjective Norm	Adapted from the TRA (see above)
		Image	"the degree to which use of an innovation is perceived to enhance one's … status in one's social system." (Venkatesh & Davis, 2000, p. 189)
		Job Relevance	"an individual's perception regarding the degree to which the target system is applicable to his or her job." (Venkatesh & Davis, 2000, p. 191)
		Output Quality	"over and above considerations of what tasks a system is capable of performing and the degree to which those tasks match their job goals (job relevance), people will take into consideration how well the system performs those tasks, which we refer to as perceptions of output quality." (Venkatesh & Davis, 2000, p. 191)
		Result Demonstrability	"the tangibility of the results of using the innovation," (Venkatesh & Davis, 2000, p. 192)
		Voluntariness	"the extent to which potential adopters perceive the adoption decision to be non-mandatory" (Venkatesh & Davis, 2000, p. 188)
Venkatesh and Bala (2008)	TAM 3	The TAM 2 variables	See above
		Computer Self-Efficacy	The degree to which an individual believes that he or she has the ability to perform a specific task/job using the computer (Compeau & Higgins, 1995a, 1995b as cited in Venkatesh and Bala, 2008, p. 277)
		Perception of External Control	"Perceptions of external control are related to individuals' control beliefs regarding the availability of organizational resources and support structure to facilitate the use of a system" (Venkatesh & Bala, 2008, p. 278)
		Computer Anxiety	"an individual's apprehension, or even fear, when she/he is faced with the possibility of using computers" (Venkatesh, 2000, p. 349).
		Computer Playfulness	"…the degree of cognitive spontaneity in microcomputer interactions" (Webster & Martocchio, 1992, p. 204)
		Perceived Enjoyment	"the extent to which the activity of using a specific system is perceived to be enjoyable in its own right, aside from any performance consequences resulting from system use." (Venkatesh, 2000, p. 351)
		Objective Usability	"is a construct that allows for a comparison of systems based on the actual level (rather than perceptions) of effort required to complete specific tasks." (Venkatesh, 2000, pp. 350–351)

Table 1 (continued)

Author/s	Model/Theory	Components	Component's Definitions
Venkatesh et al. (2003)	Unified Theory of Acceptance and Use of Technology (UTAUT)	Performance expectancy	"is defined as the degree to which an individual believes that using the system will help him or her to attain gains in job performance." (Venkatesh et al., 2003, p. 447)
		Effort expectancy	"is defined as the degree of ease associated with the use of the system" (Venkatesh et al., 2003, p. 450)
		Social influence	"the degree to which an individual perceives that important others believe he or she should use the new system" (Venkatesh et al., 2003, p. 451)
		Facilitating conditions	"the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system" (Venkatesh et al., 2003, p. 453)
Rogers (1995)	Innovation Diffusion Theory (IDT)	Relative Advantage	"the degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers, 1995, p. 213)
		Compatibility	"the degree to which an innovation is perceived as being consistent with the existing values, past experiences and needs of potential adopters" (Rogers, 1995, p. 224)
		Complexity	"the degree to which an innovation is perceived as relatively difficult to understand and use" (Rogers, 1995, p. 242)
		Trialability	"the degree to which an innovation may be experimented with on a limited basis" (Rogers, 1995, p. 243)
		Observability	"the degree to which the results of an innovation are visible to others" (Rogers, 1985, p. 244)

beliefs around their intentions to use Web 2.0 tools in their future teaching (Sadaf et al., 2012).

The Technology Acceptance Model (TAM) (Davis, 1989; Davis et al., 1989) was developed exclusively to predict individuals' behavioral intention to use technology. According to the TAM, an individual's intention is influenced by attitude and perceived usefulness, i.e., the extent to which a person believes that using a specific technology will enhance his or her job performance. The TAM also has a fourth construct – perceived ease of use. This construct is hypothesized to influence attitude and perceived usefulness. In general, as the individual's perceived ease of use of a specific technology increases their attitude toward this use, as well as its perceived usefulness, should become more positive. The TAM has been used in a significant number of studies which looked at the acceptance of various digital technologies in education and was found to remain a valid model for describing pre-service and in-service teachers' technology use intentions (Scherer & Teo, 2019; Scherer et al., 2019). However, to increase the TAM's prediction accuracy, other researchers added new constructs. An initial model which emerged, as a result, was the decomposed Theory of Planned Behavior (C-TAM-TPB) (Taylor & Todd, 1995). In this model, Taylor and Todd (1995) used all existing constructs in the TAM and TPB, and added six new constructs. As we can see in Table 1, the authors added the construct of compatibility to the TAM, which, together with perceived usefulness and ease of use, is theorized to influence attitude. Furthermore, they added peer influence and superiors' influence as determinants of subjective norms. Next, they added the constructs self-efficacy, the resource facilitating condition, and technology facilitating condition, which they assert influences perceived behavioral control. Researchers have utilized this new theory in several studies with teachers, by investigating the beliefs contributing to pre-service and in-service teachers' intentions to use computer applications in their teaching (Smarkola, 2008), their adoption of mobile phone messages as a parent-teacher communication medium (Ho et al., 2013) and their acceptance and use of an educational portal (Pynoo et al., 2012).

Another acceptance model, which is an extension to the TAM, is the TAM2 (Venkatesh & Davis, 2000). In the TAM2, Venkatesh and Davis (2000) added "social influence processes (subjective norms, voluntariness, and image) and cognitive instrumental processes (job relevance, output quality, result demonstrability, and perceived ease of use)" (p. 198) as factors that affect perceived usefulness and intention. Several researchers have used the TAM2 to investigate pre-service and in-service teachers' acceptance of various technologies, such as social media in teaching (Acarli & Sağlam, 2015) and learning management systems (De Smet et al., 2012).

Venkatesh et al. (2003) proposed the Unified Theory of Acceptance and Use of Technology (UTAUT) theorizing that the constructs of performance expectancy, effort expectancy, social influence, and facilitating conditions are important factors for technology acceptance across organizational contexts. Later, Venkatesh et al. (2012) developed the UTAUT2 which incorporated three new constructs into the original UTAUT. These were hedonic motivation, price value, and habit. A recent systematic literature review regarding the UTAUT2 conducted by Tamilmani et al. (2021) showed that this new model is a high-quality theory for most dimensions. Although the UTAUT was developed to understand various intentions and behaviors in organizational and consumer contexts, it has also been used to explain the acceptance of digital technologies in education. For instance, Teo and Noyes (2014) used the UTAUT to investigate pre-service teachers' intentions to use information technology and found it to be a useful model in explaining their intention. More recently, Yildiz Durak (2019) investigated the factors affecting pre-service teachers' acceptance and use of social networking sites for educational purposes. The results of this study showed that social impact had the greatest effect on pre-service teachers' acceptance. On the contrary, the UTAUT2 has been used in a small number of studies featuring teacher samples (see Tamilmani et al., 2021). Mtebe et al. (2016) investigated the factors affecting Tanzanian teachers' acceptance and prolonged use of developed multimedia-enhanced content. The results showed that aside from performance expectancy all constructs of the UTAUT2 affected teachers' acceptance and use.

Another model that was proposed to examine innovation acceptance, such as technologies, is the Innovation Diffusion Theory (IDF) (Rogers, 1995). Rogers defined innovation as "an idea, practice, or object that is perceived as new by an individual or another unit of adoption" (Rogers, 1995, p. 11), and diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 1995, p. 5). According to the IDF, the diffusion of an innovation such as digital technology could be achieved when the five perceived attributes listed in Table 1 are present: relative advantage, compatibility, complexity, trialability, and observability. Individuals' perceptions of these attributes influence the acceptance or rejection of an innovation. This theory has also been used in education. For example, Li and Huang (2016) investigated the factors that affect (non-adopters vs. early adopters) teachers' adoption of game-based learning in elementary schools and Sahin (2012) examined pre-service teachers' perspectives on the diffusion of ICTs in elementary education.

2.1 Technology acceptance models and mobile augmented reality in education

Although there are numerous studies that have examined the acceptance of digital technologies in teaching by pre-service and in-service teachers, the number of studies regarding MAR acceptance is limited. Table 2 lists the studies which have used acceptance models to study MAR as well as the results indicating relationships between the components investigated.

Table 2 also shows the studies which used the TAM or added other variables to it. One of the studies that applied the TAM was conducted by Pasalidou and Fachantidis (2021). They studied the relationship between the components of perceived usefulness and perceived ease of use on in-service teachers' intention to use a particular AR app about the moon. Ibili et al. (2019) used the TAM together with the components of anxiety, social norms, and satisfaction to investigate the acceptance of an Augmented Reality Geometry Tutorial System (ARGTS) by mathematics teachers. More specifically, in their model, they hypothesized that teachers' intention is affected by their attitude toward the ARGTS' use, which, in turn, is affected by their satisfaction with and perceived usefulness of ARGTS. In addition, Ibili et al. (2019) hypothesized that intention is influenced by ARGTS user satisfaction and social norms. In turn, satisfaction and perceived usefulness are influenced by perceived ease of use. Ibili et al. (2019) further hypothesized that these last two components are affected by social norms and anxiety.

Jang et al. (2021) developed the existing TAM to create a new model, the extended Technology Acceptance Model (eTAM). In this model, TPACK was added to the TAM as a component hypothesized to influence perceived ease of use and perceived usefulness. Furthermore, the social norm was added as a component hypothesized to influence perceived usefulness, while motivation support was added as a component which influences perceived ease of use. The eTAM was applied to a sample of in-service teachers to investigate their intention to use AR and Virtual Reality (VR) technologies in teaching.

Asiri and El-Aasar (2022) used the TAM, as well as the components of anxiety and facilitating conditions, as determinants of perceived ease of use and perceived benefit (i.e., perceived usefulness). In another study, Rahmat and Mohamad (2021) used the TAM and the user-interface design component to examine pre-service teachers' readiness to use MAR in their future classrooms. Cabero-Almenara et al. (2019) used the TAM as a theoretical framework to examine pre-service teachers' acceptance of AR learning objects. Specifically, they used the TAM and the following three components: achievement, perceived enjoyment, and technical quality. In this new model,

Table 2 Technology acceptance models investigating pre-service and in-service teachers' acceptance of MAR in primary and secondary education

Author(s)	Aim	Sample	Model and components	Significant effects
		In-service teachers		
Pasalidou and Fachantidis (2021)	To examine teachers' intention to integrate the mobile AR app about the moon.	206 Greek primary school teachers	TAM: Perceived usefulness (PU), Perceived ease of use (PEU) and Behavioral intention (BI)	1) PU → BI, 2) PEU → BI, 3) PEU → PU
Ibili et al. (2019)	To examine teachers' acceptance and intention to use an Augmented Reality Geometry Tutorial System (ARGTS)	148 Turkish mathematics teachers	Based on the TAM: Usefulness (PU), Satisfaction (SF), Behavioral Intention (BI), Anxiety (ANX), Perceived Ease of Use (PEU), Social Norms (SN) and Attitude (AT)	1) PEU → PU, 2) PU → AT, 3) AT → BI, 4) PU → SF, 5) SF → AT, 6) PEU → SF, 7) SN → PU, 8) SN → PEU, 9) ANX → PEU
Jang et al. (2021)	To identify the factors that influence teachers' intention to use AR and VR technology	292 in-service Korean elementary school teachers	Extended Technology Acceptance Model (eTAM): Perceived Usefulness (PU), Perceived Ease of Use (PEU) and Behavioral Intention (BI), Technological pedagogical and content knowledge (TPACK), Social norm (SN), Motivational support (MS)	1) ATU → BI, 2) PEU → ATU, 3) PU → ATU, 4) PEU → PU, 5) TPACK → PU, 6) TPACK → PEU, 7) SN → PU, 8) MS → PEU
Ma et al. (2021)	To explore teachers' acceptance of AR technology	213 Chinese K-12 teachers	Based on the TAM3: Perceived usefulness (PU), Perceived ease of use (PEOU), Self-efficacy (SE), External environment (EE), System characteristics (SC), Use intention (UI), and Use behavior of AR (UB).	1) UI → UB, 2) PU → UI, 3) PEOU → UI, 4) PEOU → PU, 5) SE → UI, 6) PEOU → SE, 7) EE → UI, 8) SC → PU, 9) SC → PEOU, 10) SC → SE
Asiri and El-Aasar (2022)	To examine teachers' acceptance of AR and their perceptions on the expected benefits of AR applications	127 teachers from the schools of Najran city	Based on the TAM: Behavioral intention (BI), Attitude, to use (ATU), Perceived benefit (PB), Anxiety (ANX), Facilitating conditions (FC)	1) ANX → PEU, 2) PEU → ATU, 3) PEU → PB, 4) PB → ATU, 5) PB → BI
Ateş and Garzón (2023)	To examine: (a) teachers' intentions to use AR in their classrooms, (b) the explanatory power of the proposed model, compared to the TPB and UTAUT2	451 Turkish science teachers	The TPB and UTAT2: Attitude (A), Subjective Norm (SN), Perceived Behavioral Control (PBC), Performance Expectancy (PE), Effort Expectancy (EE), Facilitating Conditions (FC), Hedonic Motivation (HM), Price Value (PV), Habit (H), Intention (I)	1) A → I, 2) SN → I, 3) PBC → I, 4) PE → I, 5) EE → I, 6) FC → I, 7) HM → I, 8) PV → I, 9) H → I
		Pre-service and In-service teachers		
Ning et al. (2019)	To investigate pre-service teachers' and in-service teachers' acceptance of AR technology	70 pre-service and 50 in-service teachers	UTAUT: Social influence (SI), Facilitating condition (FC), Performance expectation (PE), Effort expectation (EE)	1) EE → UB, 2) SI → UB, 3) FC → UB, 4) PE → UB

Table 2 (continued)

Author(s)	Aim	Sample	Model and components	Significant effects
		Pre-service teachers		
Nizar et al. (2019)	To examine factors that influence pre-service teachers' use behavior of the Mobile Augmented Reality Learning Cardiovascular app (MARLCardio)	75 pre-service teachers at one public university in Malaysia	UTAUT: Performance expectancy (PE), Effort expectancy (EE), Social influence (SI), Facilitating conditions (FC), Use behavior (UB)	1) EE → UB, 2) SI → UB, 3) FC → UB
Rahmat and Mohamad (2021)	To examine pre-service teachers' readiness toward integrating MAR technology into their learning and future teaching process	303 Malaysian pre-service teachers	Based on the TAM: Perceived Usefulness (PU), Perceived Ease of Use (PEU), Actual Use (AU), User-interface Design (UID)	1) PU → AU, 2) PEU → PU, 3) UID → PU, 4) UID → PEU
Cabero-Almenara et al. (2019)	To understand "the degree of technological acceptance of students during their interaction with the AR objects produced, the performance achieved by the students, and if their gender affected their acquisition of knowledge" (Cabero-Almenara et al., 2019, p. 1)	396 university students in the Faculty of Education at the University of Seville	Based on the TAM: Achievement (A), Intention to use (IU), Attitude use (AU), Perceived usefulness (PU), Perceived ease of use (PEU), Perceived enjoyment (PE), Technical quality (TQ)	1) TQ → PE, EOU, PU, 2) PEU → PE, PU, AU 3) PU → PE, AU, IU 4) PE → AU, 5) AU → IU

they hypothesized that intention influences achievement, while perceived enjoyment influences attitude, intention, and achievement. In turn, perceived enjoyment was hypothesized to influence perceived usefulness and perceived ease of use. Furthermore, Cabero-Almenara et al. (2019) used technical quality and gender in their new model as determinants of perceived usefulness, perceived ease of use, and perceived enjoyment.

The study by Ma et al. (2021) relied on the TAM3 to investigate teachers' acceptance of AR technology. According to the TAM3, behavior is affected by intention, which, in turn, is affected by perceived usefulness, perceived ease of use, self-efficacy, and external environment. In addition, Ma et al. (2021) hypothesized that perceived ease of use affects perceived usefulness and self-efficacy. Finally, these three components are all affected by system characteristics.

Other studies used the UTAUT's theoretical framework. For example, Nizar et al. (2019) used the UTAUT to determine the factors that influence pre-service teachers to use a specific MAR app named MARLCardio. The UTAUT was also used by Ning et al. (2019) to investigate pre-service and in-service teachers' intention to use AR in their teaching. More recently, Ateş and Garzón (2023) combined the TPB and the UTAUT2 to investigate science teachers' intention to use AR in their classrooms. They hypothesized that all components from these two models, which they included in their new combined model, affect teachers' intention.

The above review shows that only a few previous studies have investigated pre-service and in-service teachers' acceptance of MAR in teaching. This small number of studies, together with their limitations, which were mentioned in the introduction, led us to propose a new model and apply it to both pre-service and in-service teachers. This model and the corresponding hypotheses are presented in the next section.

3 Research model and hypotheses

The Model of Augmented Reality Acceptance (MARAM) was developed from the above literature on the theories and models of technology acceptance, along with existing MAR studies conducted with pre-service and in-service teachers. The MARAM includes eight components as shown in Fig. 1.

The TAM's conceptual framework is the basis for MARAM. As shown earlier, the TAM components constitute the core for most extended technology acceptance models. These components were used in most of the studies that investigated the acceptance of MAR by pre-service and in-service teachers. Furthermore, previous meta-analysis studies which used the TAM in educational contexts (Scherer & Teo, 2019; Scherer et al., 2019; Šumak et al., 2011) found that perceived ease of use and perceived usefulness remain valid components in studying teachers' attitudes and intentions toward the use of various digital technologies. Applying TAM components to the MARAM assumes that the greater the perception of MAR's usefulness and ease of use by pre-service and in-service teachers, the more positive their attitudes toward using MAR in their teaching. Consequently, pre-service and in-service teachers demonstrate a stronger intention to implement this technology in schools. All the above, configure the seven hypotheses that constitute the MARAM.

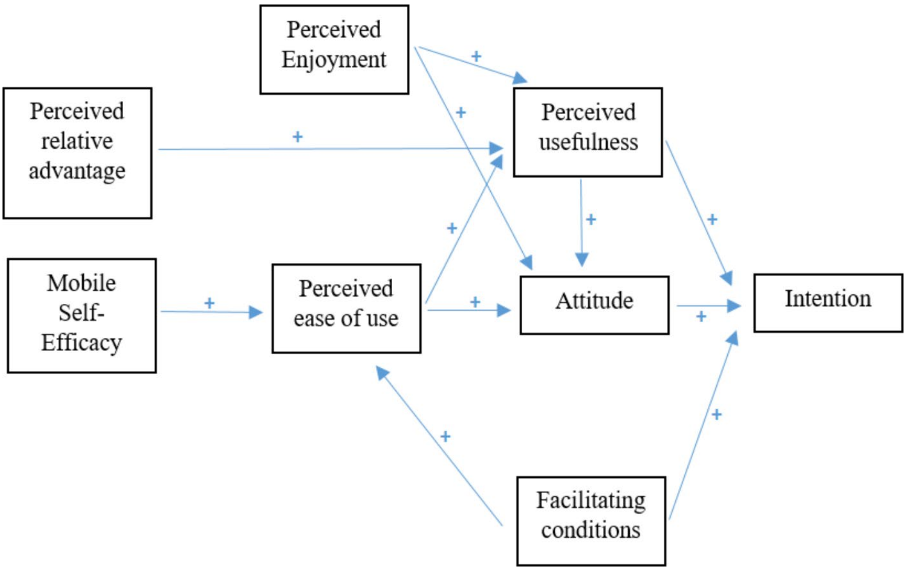

Fig. 1 The Mobile Augmented Reality Acceptance Model (MARAM)

Hypothesis 1a Pre-service and in-service teachers' perceived ease of use (PEOU) has a positive effect on their perceived usefulness (PU).

Hypothesis 1b Pre-service and in-service teachers' perceived ease of use (PEOU) has a positive effect on their attitude (Att).

Hypothesis 2a a. Pre-service and in-service teachers' perceived usefulness (PU) has a positive effect on their attitude (Att).

Hypothesis 2b b. Pre-service and in-service teachers' perceived usefulness (PU) has a positive effect on their intention (I).

Hypothesis 3 Pre-service and in-service teachers' attitude (Att) has a positive effect on their intention (I).

We also included the facilitating conditions (FC) component to the MARAM, which was introduced in the UTAUT model. According to Venkatesh et al. (2003), the acceptance of digital technologies is largely dependent upon the organizational and technical infrastructure of an establishment, as well as the degree to which a user of technology believes that this infrastructure is available to support them in its practical use. Therefore, we propose that facilitating conditions refer to pre-service and in-service teachers' belief that the appropriate conditions (e.g., Internet connection, hardware, knowledge, time) necessary to use MAR for educational purposes are present. Previous research has shown that facilitating conditions influence perceived ease of use (e.g., Bai et al., 2021; Khlaisang et al., 2021; Sukendro et al., 2020; Zarafshani et al., 2020) and intention (e.g., Taheri et al., 2022; Songkram et al., 2023; Venkatesh et al., 2003). For instance, Huang et al. (2021) demonstrated that facilitating conditions predicted teachers' perceived ease of use in their non-volitional online teaching intentions. More recently, Mukminin et al. (2023) confirmed that the facilitating condition is a significant factor that influences pre-service English teachers' perceived ease of use of social media for English writing. Also, a more recent study conducted by Songkram et al. (2023), indicated that facilitating conditions is a significant predictor of students' perceived ease of use and behavioral intentions toward a digital learning platform. Thus, the following hypotheses 4a and 4b emerge.

Hypothesis 4a Pre-service and in-service teachers' perceived facilitating conditions (FC) have a positive effect on their perceived ease of use (PEOU).

Hypothesis 4b Pre-service and in-service teachers' perceived facilitating conditions (FC) have a positive effect on their intention (I).

Furthermore, to the MARAM, we added the perceived relative advantage (PRA) component, which, as we saw in the previous section, was proposed in the IDT (Rogers, 1995). Although this component was considered similar to the TAM's perceived usefulness (Karahanna et al., 2002), we consider them to be conceptually different in the proposed MARAM, as indicated by a recent study that used perceived relative advantage to measure the adoption of mobile applications (Swani, 2021). In the MARAM, perceived usefulness relates to pre-service and in-service teachers' general beliefs about MAR's usefulness in teaching. On the contrary, perceived relative advantage refers to the affordances and added value the MAR and its use offers in teaching compared to other digital technologies teachers are familiar with or have used up until that point. The perceived relative advantage component has been used in several technology acceptance models across various fields (Almaiah et al., 2022; Khlaisang et al., 2021; Mombeuil, 2020; Owusu et al., 2021). For example, in the education field, Al-Rahmi et al. (2021) and Alyoussef (2022), adopted perceived relative advantage to explain students' intentions to use a MOOC system and Flipped Classroom respectively. They found that perceived relative advantage influences students' perceived usefulness. Similar results can be found in the study by Al-Rahmi et al. (2019), who showed that students' perceived usefulness of an e-learning system is influenced by perceived relative advantage. Based on the results of prior studies, the MARAM assumes that pre-service and in-service teachers possessing a high degree of perceived relative advantage toward MAR could consider this technology to have more positive perceived usefulness, thus giving rise to the fifth hypothesis.

Hypothesis 5 Pre-service and in-service teachers' perceived relative advantage (PRA) has a positive effect on their perceived usefulness (PU).

Another component added to the MARAM is perceived enjoyment (PE). We posit that pre-service and in-service teachers who believe that the use of MAR is enjoyable or fun in their teaching will show a greater positive attitude toward the use of MAR and perceive it to be more useful. The positive association of perceived enjoyment, attitude and perceived usefulness is supported by previous studies that investigated the acceptance of technologies (Lee et al., 2019; Teo & Noyes, 2011). Thus, we formulate hypotheses 6a and 6b.

Hypothesis 6a Pre-service and in-service teachers' perceived enjoyment (PE) has a positive effect on their attitude (Att).

Hypothesis 6b Pre-service and in-service teachers' perceived enjoyment (PE) has a positive effect on their perceived usefulness (PU).

Finally, the component of mobile self-efficacy (MSE) was added to the MARAM. This component was introduced by Nikou and Economides (2017) and is defined as "an individual's perceptions of his or her ability to use mobile devices in order to accomplish particular tasks" (p. 61). They studied the acceptance of mobile-based assessments among 145 senior high school students and found mobile self-efficacy was positively associated with perceived ease of use. Recently, Mensah (2022) found that this component positively affected the perceived ease of use of m-health services. Similar findings were found by Song et al. (2022) on the factors that influence older adults' adoption of voice-user interface. Based on these findings, we assume that the more self-confidence pre-service and in-service teachers have in the use of various applications on their mobile devices, the easier they may find it to use MAR in their teaching.

Hypothesis 7 Pre-service and in-service teachers' Mobile Self-Efficacy (MSE) has a positive effect on their perceived ease of use (PEOU).

4 Methodology

The research methodology is quantitative, and data was collected through an online questionnaire. The sample consisted of pre-service and in-service teachers, who participated in the research voluntarily, after having documented their informed consent. All analyses were performed in R statistical package.

4.1 Participants

The sample of the present study consisted of 306 Greek pre-service and in-service teachers. Among them, 137 (44.8%) were pre-service and 169 (55.2%) in-service teachers. The sample of pre-service teachers (i.e., undergraduate students - future primary school teachers) attended the Department of Primary Education, University of Ioannina and was composed of 115 (83.9%) women and 22 (16.1%) men. They were seniors, in their fourth and final year of studies, and their mean year of age was 24.15 (SD = 5.92). The sample of in-service teachers consisted of 144 (85.2%) women and 25 (14.8%) men. They were studying ICT in Education at the Department of Education of the National and Kapodistrian University of Athens, at the post-graduate level or were enrolled in a teacher training seminar.

4.2 Instrument

The study's questionnaire consisted of two sections. The first section included demographic information (e.g., gender). The second section consisted of 29 items measuring the eight components of the proposed MARAM model (see Fig. 1). These items were adapted from validated scales used in earlier technology acceptance studies. Table 3 presents the number of items under each of the eight components as well as the earlier studies from which they were adopted.

A three-phase process was undertaken to develop the final version of the questionnaire's second section. In the first phase, the back-translation method was used, with the questionnaire being translated into Greek and then back into English by two bilingual researchers. In the second phase, the clarity and wording of the Greek version of the questionnaire were examined by three researchers in AR technologies and two academic experts on digital technologies in education. In the third phase, the questionnaire was pilot tested by five pre-service teachers and eight in-service teachers. The final questionnaire was created in Google Forms and delivered separately to pre-service and in-service teachers. The second section of the questionnaire used a 5-point Likert-type scale (i.e., 1 = Strongly disagree – 5 = Strongly agree). Table 4 presents the final version of the MARAM's 29 items.

Table 3 List of MARAM components and number of items for each, as well as studies from which they were adopted

Components	Number of items	Adapted from:
Intention (I)	3	Ajzen and Fishbein (1980)
Attitude (Att)	3	Davis (1989)
Perceived ease of use (PEOU)	3	Davis (1989)
Perceived usefulness (PU)	3	Davis (1989)
Perceived relative advantage (PRA)	5	Wu et al. (2016), Turhan (2013), Kim et al. (2017), Yoon et al. (2020)
Facilitating conditions (FC)	3	Venkatesh et al. (2003)
Perceived enjoyment (PE)	4	Venkatesh and Bala (2008)
Mobile Self-Efficacy (MSE)	5	Nikou and Economides (2017), Reychav et al. (2019)

4.3 Procedure

Both pre-service and in-service teacher samples were involved in the design and development of a series of MAR applications. The sample of pre-service teachers developed their applications within the framework of the course "Project Development with Emerging Learning Technologies" during the 2021 spring semester (March to June). Specifically, each pre-service teacher used the marker-based AR platform BlippAR to augment various chapters of primary school textbooks using a variety of digital objects (i.e., 3D objects, pictures, videos, links). During the semester, each student augmented 10–12 chapters of school textbooks. Augmenting these books followed the learning objectives set by the pre-service teachers according to the revised Bloom's cognitive taxonomy. Pre-service teachers worked alone at home, while the professor of the course served as a facilitator through teleconference meetings and helped students whenever they encountered technical issues or difficulties with the augmentation process.

The sample of in-service teachers designed and developed MAR applications within the framework of a MAR training seminar delivered via the ZOOM platform in the Spring of 2020. The seminar was held from March until mid-April 2020 (for a total of 12 h), organized by the university, and composed of two parts. The first part focused on informing in-service teachers about MAR affordances in education. The second part presented in-service teachers with four tools and platforms used to develop image-based and location-based augmented reality applications (i.e., ARIS, Zapworks, BlippAR and ROAR). During this second part, the in-service teachers were asked to develop an indicative example of augmented reality for a subject area using each of the aforementioned tools. Following the completion of this process, both samples were given a URL in Google Forms to complete the study's questionnaire.

Table 4 Means (M) and Standard Deviations (SD) for components of MARAM

MARAM components	Total		Pre-service teachers		In-service teachers	
	M	SD	M	SD	M	SD
Intention	4.08	0.67	3.93	0.70	4.21	0.62
I intend to use AR applications in my future teaching.	4.27	0.67	4.06	0.72	4.45	0.58
I plan to use AR applications in my future teaching.	3.94	0.80	3.84	0.77	4.02	0.82
I predict I will use AR applications in my future teaching.	4.03	0.81	3.89	0.77	4.15	0.82
Attitude	**4.28**	**0.59**	**4.12**	**0.65**	**4.41**	**0.51**
Using AR applications is a good idea.	4.44	0.58	4.28	0.63	4.56	0.51
I like using AR applications.	4.20	0.70	4.00	0.75	4.36	0.61
It is desirable to use AR applications.	4.19	0.71	4.07	0.74	4.30	0.67
Perceived ease of use	**3.70**	**0.78**	**3.48**	**0.79**	**3.88**	**0.74**
My interaction with AR applications is clear and understandable.	3.77	0.83	3.62	0.85	3.89	0.80
It is easy for me to become skillful at using AR applications.	3.78	0.89	3.53	0.87	3.98	0.86
I find AR applications easy to use.	3.56	0.90	3.31	0.91	3.76	0.84
Perceived usefulness	**4.08**	**0.69**	**4.03**	**0.75**	**4.13**	**0.63**
Using AR applications enhances my teaching effectiveness.	4.11	0.74	4.03	0.83	4.18	0.66
AR applications are useful for my teaching.	4.13	0.75	4.06	0.83	4.18	0.67
Using AR applications increases my teaching productivity.	4.01	0.76	4.00	0.78	4.02	0.75
Perceived relative advantage	**3.72**	**0.60**	**3.70**	**0.63**	**3.74**	**0.57**
AR applications would be more advantageous in my teaching than other technologies.	3.71	0.74	3.65	0.74	3.76	0.73
AR applications would make my teaching more effective than other technologies.	3.64	0.75	3.62	0.75	3.66	0.75
AR applications are relatively efficient in my teaching compared to existing technologies.	3.68	0.72	3.69	0.70	3.66	0.73
The use of AR applications offers new learning opportunities compared to existing technologies.	4.07	0.65	3.95	0.73	4.16	0.55
Overall, AR applications are better than existing technologies.	3.50	0.77	3.58	0.76	3.43	0.77
Facilitating conditions	**3.39**	**0.76**	**3.45**	**0.75**	**3.34**	**0.76**
I have the resources (e.g., Internet connection, tablets) necessary to use AR applications in my teaching.	3.61	1.03	3.55	1.03	3.66	1.02
I have the knowledge needed to use AR applications in my teaching.	3.34	0.92	3.42	0.89	3.27	0.94
I have the time needed to use AR applications in my teaching.	3.22	0.93	3.38	0.82	3.08	1.00
Perceived enjoyment	**4.16**	**0.65**	**4.01**	**0.72**	**4.29**	**0.57**
Using AR applications is truly fun.	4.26	0.69	4.09	0.77	4.40	0.58
I know using AR applications to be enjoyable.	4.22	0.70	4.07	0.77	4.34	0.61
The use of AR applications gives me pleasure.	4.13	0.76	3.96	0.81	4.27	0.69
The use of AR applications makes me feel good.	4.04	0.77	3.91	0.81	4.15	0.71
Mobile Self-Efficacy	**3.82**	**0.65**	**3.70**	**0.71**	**3.92**	**0.59**
I could complete a job or task using a mobile device.	3.77	0.88	3.67	0.92	3.86	0.83
I could complete a job or task using a mobile device if someone showed me how to do it.	4.01	0.91	3.91	0.99	4.09	0.83
I was fully able to use a mobile device before I began using AR applications.	3.94	0.90	3.84	0.92	4.03	0.87
I am confident that I can effectively use AR applications using mobile technology.	3.80	0.84	3.62	0.86	3.94	0.81
I believe I can use AR applications using mobile technology even if I have never used a similar technology before.	3.58	0.93	3.47	0.93	3.67	0.92

4.4 Reliability and convergent validity

To ascertain reliability and convergent validity, we determined Cronbach's alpha, composite reliability (CR), average variance (AVE), and factor loading measures according to Urbach and Ahlemann (2010). We used Cronbach's alpha to assess the internal consistency of the items in each MARAM component (See Table 5). Cronbach's alpha measures internal consistency/reliability, and the degree of homogeneity among a set of items; regardless if they reflect the same construct. It ranges from 0 to 1 with values above 0.7 suggesting an acceptable level of reliability and values above 0.8 suggesting a very good fit (Cronbach, 1951). Composite reliability (CR) also measures internal consistency among scale items, similar to Cronbach's alpha. According to Fornell and Larcker (1981), this is an "indicator of the shared variance among the observed variables used as an indicator of a latent construct". Values above the 0.7 threshold indicate that the items under evaluation measure the same construct. These two indices then confirm construct validity.

We used average variance extracted (AVE) and factor loading to test for convergent validity. Weak factor loadings were eliminated from our analysis. This means loadings with a score lower than 0.4. AVE measures the variance extracted from a construct, in association with the amount of variance due to measurement error. For adequate convergence, an AVE of at least 0.5 is highly recommended.

The heterotrait-monotrait (HTMT) ratio was used to establish discriminant validity. This measure was proposed as an alternative to other two methods that detect the lack of a discriminant, which are the Fornell-Larcker (1981) criterion and (partial) cross-loadings. According to Henseler et al. (2015), the heterotrait-monotrait (HTMT) ratio is the superior method according to a Monte Carlo simulation study, and hence the other two methods will not be examined in this paper. If the HTMT value is below 0.90, discriminant validity has been established.

4.5 Structural equation modeling (SEM)

We used Structural equation modeling (SEM) with the Maximum Likelihood (ML) estimator to validate the suggested model presented in Fig. 1 (MARAM). SEM is a multivariate technique that tests and evaluates pre-assumed multivariate causal relationships between latent and observed variables. The SEM method combines two statistical procedures, confirmatory factor analysis (CFA) and path analysis. CFA uses latent variables that are indicators of observed variables and summarize their behavior. Path analysis quantifies relationships among variables (Crowley & Fan, 1997). All components are represented by latent variables with the corresponding items used as indicators of these variables. Then, from the conceptual path diagram of the MARAM in Fig. 1 we observe that the model includes four regression models. Model 1 models perceived usefulness (PU) as a function of perceived enjoyment (PE), perceived relative advantage (PRA) and perceived ease of use (PEOU). Model 2 models PEOU as a function of mobile self-efficacy (MSE) and facilitating conditions (FC). Model 3 models attitude (ATT) as a function of PE, PEOU and PU and model 4 models Intention (I) as a function of ATT, FC and PU. We calculated the Chi-square test, the Tucker-Lewis index (TLI), the comparative fit index (CFI), the standardized root mean square residual (SRMR), and the root mean square error of approximation (RMSEA) to evaluate model fit. The CFI and TLI suggested cutoff values of 0.9, 0.8 for the SRMR and for the RMSEA a value smaller than 0.05 indicates a "close fit," whereas values smaller than 0.08 suggest a reasonable model–data fit (Hooper et al., 2008). Before evaluating the model fit, we tested for multicollinearity with the Variance Inflation Factor (VIF). Multicollinearity occurs when two or more of the predictive variables are highly correlated and leads to the wrong interpretation of path coefficients. VIF values exceeding 5 or 10 indicate high multicollinearity and should be treated accordingly.

4.6 Multi-group analysis

Finally, we explored differences among pre-service teachers' and in-service teachers by performing a multi-group analysis. To employ multi-group analysis some prerequisites must apply. We tested for Measurement Invariance of the Composite Models (MICOM) by applying three steps: configural invariance, compositional invariance, and equality of composite mean values and variances (Henseler et al., 2016). To achieve a partial measurement invariance, the first two criteria should be satisfied (configural and compositional invariance). Next, a multi-group analysis compared the two groups (pre-service and in-service) and tested whether statistically significant differences exist among teacher-group parameter estimates.

5 Results

We combined the dataset and analyzed it separately for the two samples of teachers. The results of the descriptive analysis are presented in Table 4 and indicate that both samples had a positive intention to use MAR, showed a positive attitude toward its use, as well as positive views on the usefulness and enjoyment it provides. They had comparatively fewer positive perceptions toward mobile self-efficacy, perceived relative advantage, and perceived ease of use. The results also show that compared to pre-service teachers, in-service teachers scored a higher mean on all components, aside from the facilitating conditions.

We decided to remove the items that did not produce acceptable results before proceeding to the path analysis (e.g., MSE_2 loading was equal to 0.200, 0.345, and 0.033 for the total sample, pre-service, and in-service, respectively).

As Table 5 shows the results of Cronbach's, AVE, and CR for all constructs except FC, which were very satisfactory in all three cases (total sample, pre-service and in-service). For the FC construct, Cronbach's was slightly non-satisfactory for the total sample (0.698), satisfactory for pre-service (0.760), and non-satisfactory for in-service (0.661). The AVE for the FC construct was non-acceptable for both the total sample and in-service (0.450 and 0.429, respectively), but marginally sufficient for pre-service teachers (0.519). The CR for the total sample was barely acceptable (0.703), acceptable (0.703) for pre-service and marginally unacceptable (0.672) for in-service.

From the above results we decided to include the FC in the pre-service teachers and total sample analysis, and not in the in-service teachers' analysis. We re-ran the

Table 5 Assessment results for the measurement model. Loading values were estimated after excluding the items that did not give a good fit

Construct	Item	Loading			Cronbach's α			AVE			CR		
		Total sample	Pre-service	In-service	Total sample	Pre-service	In-service	Total sample	Pre-service	In-service	Total sample	Pre-service	In-service
Intention (I)	I_1	0.892	0.912	0.879	0.849	0.917	0.774	0.656	0.788	0.542	0.850	0.918	0.775
	I_2	0.826	0.897	0.753									
	I_3	0.702	0.852	0.541									
Attitude (Att)	Att_1	0.792	0.861	0.695	0.867	0.902	0.804	0.686	0.755	0.581	0.867	0.902	0.805
	Att_2	0.862	0.867	0.822									
	Att_3	0.828	0.879	0.764									
Perceive ease of use (PEOU)	PEOU_1	0.909	0.969	0.860	0.879	0.877	0.867	0.709	0.710	0.688	0.879	0.879	0.868
	PEOU_2	0.848	0.810	0.862									
	PEOU_3	0.763	0.732	0.762									
Perceived usefulness (PU)	PU_1	0.888	0.909	0.843	0.903	0.915	0.891	0.757	0.784	0.731	0.903	0.916	0.891
	PU_2	0.886	0.913	0.849									
	PU_3	0.835	0.833	0.873									
Perceived relative advantage (PRA)	PRA_1	0.820	0.910	0.720	0.880	0.907	0.859	0.598	0.661	0.552	0.881	0.906	0.859
	PRA_2	0.777	0.813	0.748									
	PRA_3	0.812	0.852	0.795									
	PRA_4	0.752	0.818	0.639									
	PRA_5	0.702	0.651	0.800									
Facilitating conditions (FC)	FC_1	0.795	0.593	X	0.698	0.760	0.661	0.450	0.519	0.429	0.703	0.761	0.672
	FC_2	0.695	0.794	X									
	FC_3	0.484	0.759	X									
Perceived enjoyment (PE)	PE_1	0.857	0.855	0.841	0.920	0.930	0.898	0.743	0.770	0.690	0.920	0.930	0.899
	PE_2	0.804	0.770	0.818									
	PE_3	0.924	0.973	0.860									
	PE_4	0.858	0.899	0.803									

Table 5 (continued)

Construct	Item	Loading			Cronbach's α			AVE			CR		
		Total sample	Pre-service	In-service	Total sample	Pre-service	In-service	Total sample	Pre-service	In-service	Total sample	Pre-service	In-service
Mobile Self-Efficacy (MSE)	MSE_1	0.705	0.770	0.649	0.825	0.843	0.802	0.551	0.580	0.514	0.828	0.844	0.806
	MSE_2	-	-	-									
	MSE_3	0.627	0.593	0.640									
	MSE_4	0.889	0.879	0.874									
	MSE_5	0.724	0.777	0.679									

Abbreviations: AVE: average variance extracted, CR: composite reliability

Table 6 SEM model fit indices for the MARAM

		CFI	TLI	RMSEA	SRMR	Chi-square / Chi-square df
Model with FC	Total sample	0.935	0.926	0.061	0.050	705.767/2.119
	In-service	0.899	0.885	0.073	0.061	627.402/1.884
	Pre-service	0.906	0.893	0.078	0.065	611.096/1.835
Model without FC	Total sample	0.928	0.918	0.069	0.068	648.819/2.467
	In-service	0.899	0.885	0.078	0.066	530.486/2.017
	Pre-service	0.888	0.873	0.093	0.095	571.116/2.172

Abbreviations: MARAM: Mobile Augmented Reality Acceptance Model; df: degrees of freedom; CFI: comparative fit index; TLI: Tucker–Lewis Index; RMSEA: root-mean-square error of approximation, SRMR: Standardized Root Mean Square Residual

Table 7 Discriminant validity for total sample: HTMT criterion

Constructs	PE	PRA	MSE	FC	PEOU	PU	Attitude	Intention
PE	-							
PRA	0.446	-						
MSE	0.517	0.426	-					
FC	0.528	0.523	0.676	-				
PEOU	0.648	0.402	0.804	0.782	-			
PU	0.639	0.617	0.441	0.483	0.478	-		
Attitude	0.758	0.557	0.505	0.541	0.580	0.687	-	
Intention	0.673	0.501	0.535	0.601	0.598	0.720	0.814	-

Table 8 Discriminant validity for in-service (upper triagonal matrix) and pre-service (lower triagonal matrix): HTMT criterion

Constructs	PE	PRA	MSE	FC	PEOU	PU	Attitude	Intention
PE	-	0.412	0.615	X	0.686	0.704	0.847	0.716
PRA	0.483	-	0.495	X	0.316	0.598	0.508	0.491
MSE	0.400	0.363	-	X	0.873	0.530	0.525	0.645
FC	0.523	0.551	0.663	-	X	X	X	X
PEOU	0.577	0.498	0.720	0.806	-	0.520	0.623	0.654
PU	0.587	0.629	0.346	0.430	0.431	-	0.723	0.723
Attitude	0.671	0.612	0.451	0.540	0.488	0.670	-	0.821
Intention	0.607	0.521	0.402	0.519	0.494	0.724	0.791	-

analyses both with and without FC. According to the calculated fit indices, the model fits were acceptable (Table 6).

The pre-service model with the FC was better than the pre-service model without the FC as expected. Also, the total sample model was better when the FC component was included. The in-service model had almost identical results with or without the FC, but according to the parsimonious principle and reliability and convergent validity, we excluded the FC from the in-service model (Table 6).

All discriminant values are smaller than 0.85 (Table 7). The same applies to pre-service teachers' discriminant validity (lower triangular matrix in Table 8). For in-service teachers (upper triangular matrix of Table 8), there is a value (0.873) that is greater than 0.850, but smaller than 0.90.

Table 9 Collinearity test by inspecting Variance inflation factor (VIF)

		PRA	PE	PEOU	PU	Att	FC	MSE	R^2	R^2_{adj}
Total sample	Model 1 (PU)	1.275	1.862	1.778					0.747	0.745
	Model 2 (Att)		2.277	1.755	1.709				0.546	0.541
	Model 3 (Intention)				1.952	2.124	1.460		0.653	0.650
	Model 4 (PEOU)						1.922	1.922	0.735	0.733
Pre-service	Model 1 (PU)	1.427	1.641	1.654					0.501	0.490
	Model 2 (Att)		1.908	1.545	1.559				0.575	0.566
	Model 3 (Intention)				1.830	2.125	1.423		0.702	0.695
	Model 4 (PEOU)						1.778	1.778	0.708	0.704
In-service	Model 1 (PU)	1.202	2.051	1.893					0.613	0.606
	Model 2 (Att)		2.741	1.899	1.992				0.749	0.744
	Model 3 (Intention)				2.082	2.082	X		0.721	0.718
	Model 4 (PEOU)						X		0.721	0.718

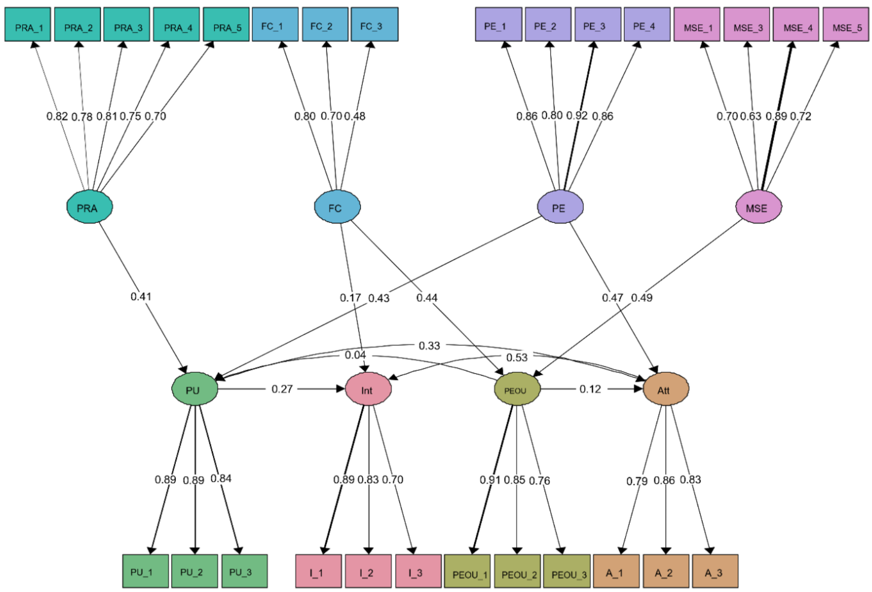

Fig. 2 SEM analysis of the MARAM (Total sample, N = 306)

We examined collinearity prior to the proposed structural relations, to ensure that our statistical inference is reliable. This was assessed by calculating the variance inflation factor (VIF) values for every model and every sample. As recommended the VIF estimates are lower than 5, indicating a lack of collinearity in all cases (Table 9). The R-squared values for the four models of the total sample, Models 1 to 4, were 0.747, 0.546, 0.653, and 0.735, respectively and interpreted as moderate to high variability (i.e., 74.7% for the first model) for each outcome variable as explained by the regression model. The same interpretation holds true for the four models of pre-service and in-service teachers (Table 9).

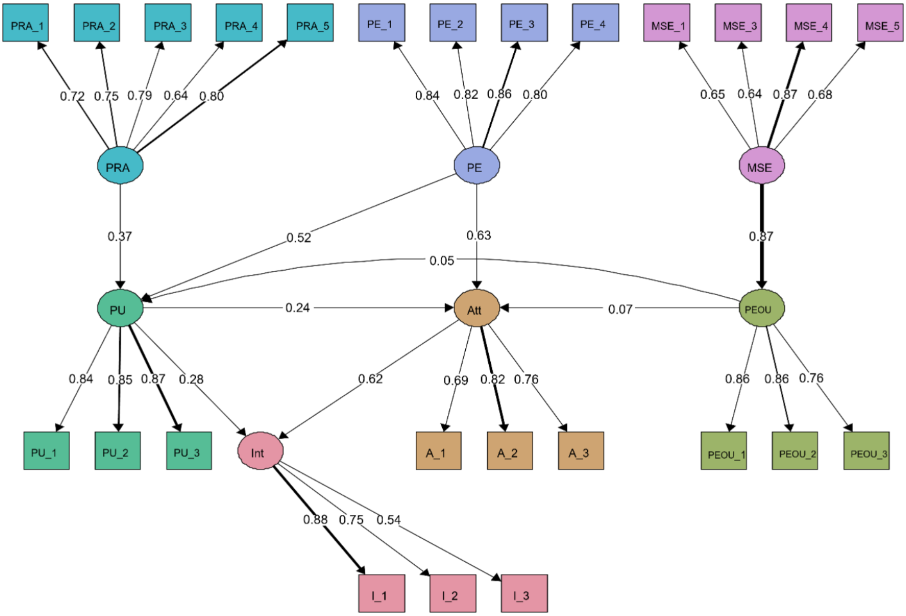

Fig. 3 SEM analysis of the MARAM (In-service teachers, N = 169)

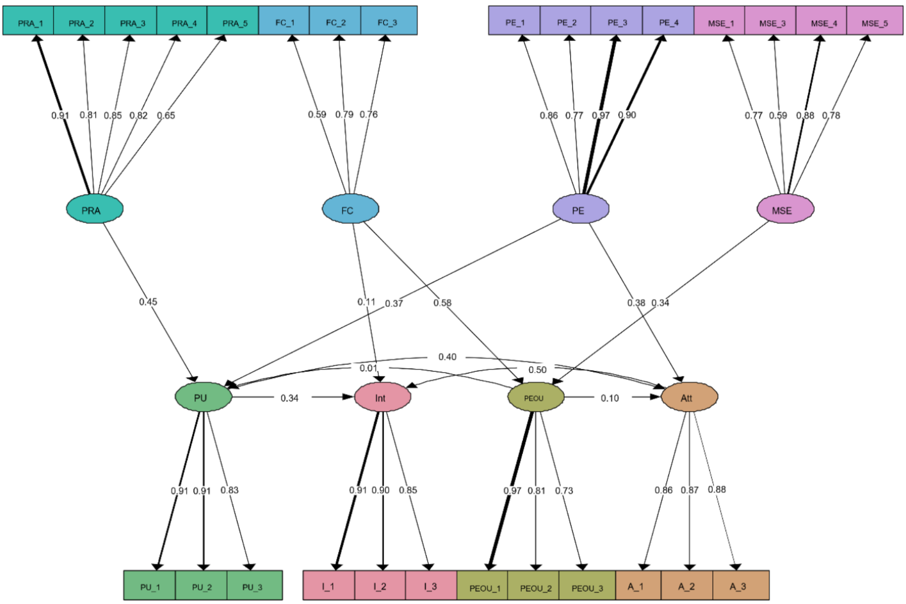

Fig. 4 SEM analysis of the MARAM (Pre-service teachers, N = 137)

Table 10 Hypothesis testing results for the total sample (N=306), in-service teachers (N=169) and pre-service teachers (N=137)

Hypotheses	Path	Total sample			Pre-service teachers			In-service teachers		
		Estimate (Std. error)	p-value	Supported	Estimate (Std. error)	p-value	Supported	Estimate (Std. error)	p-value	Supported
H1a	PEOU → PU	0.036 (0.073)	0.622	No	0.002 (0.100)	0.987	No	0.050 (0.087)	0.566	No
H1b	PEOU → Att	0.119 (0.065)	0.066	No	0.097 (0.092)	0.294	No	0.068 (0.095)	0.475	No
H2a	PU → Att	0.327 (0.071)	<0.001	Yes	0.404 (0.096)	<0.001	Yes	0.244 (0.107)	0.022	Yes
H2b	PU → I	0.275 (0.069)	<0.001	Yes	0.344 (0.080)	<0.001	Yes	0.282 (0.140)	0.044	Yes
H3	Att → I	0.533 (0.080)	<0.001	Yes	0.503 (0.112)	<0.001	Yes	0.623 (0.138)	<0.001	Yes
H4a	FC → PEOU	0.445 (0.079)	<0.001	Yes	0.580 (0.099)	<0.001	Yes	-	-	-
H4b	FC → I	0.172 (0.074)	0.020	Yes	0.106 (0.090)	0.242	No	-	-	-
H5	PRA → PU	0.409 (0.058)	<0.001	Yes	0.451 (0.089)	<0.001	Yes	0.372 (0.074)	<0.001	Yes
H6a	PE → Att	0.473 (0.080)	<0.001	Yes	0.381 (0.104)	<0.001	Yes	0.627 (0.128)	<0.001	Yes
H6b	PE → PU	0.434 (0.073)	<0.001	Yes	0.368 (0.091)	<0.001	Yes	0.518 (0.096)	<0.001	Yes
H7	MSE → PEOU	0.495 (0.073)	<0.001	Yes	0.337 (0.106)	0.002	Yes	0.869 (0.043)	<0.001	Yes

Note: p-value<0.05 denotes statistically significant

We tested the MARAM using SEM on the total sample of both pre-service and in-service teachers. Figure 2 shows the results of the SEM model for the total sample. Latent variables are represented by ovals and observed variables by rectangles. We presented standardized loadings (the coefficients from latent to observed variables) and standardized regression coefficients (arrows pointing from latent to other latent variables). Loadings and coefficients close to one show strong relationships while values close to zero reflect weak relationships. The loadings for every factor in the total sample are quite satisfactory (Fig. 2). The same graphs for in-service teachers and pre-service teachers can be found in Figs. 3 and 4.

Table 10 shows the results of hypotheses testing, where all models agree that H1a and H1b should be rejected for every sample. This can also be seen in the graph (Fig. 2), since the standardized coefficients of PEOU in PU and of PEOU in Att are low. The results we trust the most are those of the total sample since the larger the sample size, the greater the power of our analysis. We next conduct a multi-group analysis to compare the results of pre-service and in-service teachers.

5.1 Multi-group analysis

The configural invariance involves three criteria: (i) identical indicators per measurement model, (ii) identical data treatment, and (iii) identical algorithm settings or optimization criteria. As this does not apply to our groups (exclusion of FC from the in-service), we decided to perform two multi-group analyses: one with both pre-service and in-service containing the FC, and one without the FC. Given that the requirements are satisfied, configural invariance has been proven.

The (ii) criterion of MICOM is established when composite scores are equally distributed across groups. Table 11 shows the results of this analysis. As observed, the FC component did not achieve compositional invariance and hence will not be checked for the (iii) criterion. In contrast, the other components achieved at least partial measurement invariance. The (iii) criterion has two scales, one that tests for differences between the group means and one that tests for the log of the ratio of the group variances. Table 11 shows that components PRA and PU have achieved full measurement invariance.

Table 12 presents the path estimate coefficients and confidence intervals for both pre-service and in-service teachers. In the Overlap column, “Yes” indicates that overlap exists and “No” that it does not. We also present Henseler’s p-value because the overlap method fails to reject the null hypothesis more frequently than a hypothesis testing procedure. By checking for overlap to confirm statistical differences, we consequently decrease statistical power (higher type II error rate) which might overlook essential findings.

The results in Table 13 show that a difference exists for both pre-service and in-service teachers as indicated in the path differences, but these differences were not statistically significant. The only statistically significant difference concerns the FC component, which is not taken into consideration since no compositional invariance could be established. The results of Henseler’s p-value in Table 14 for the multi-group analysis (without the FC component) indicate that there is only one statistically significant difference in the MES -> PEOU path for the in-service and pre-service teachers’ models

6 Discussion and conclusions

This research examines critical factors influencing pre-service and in-service teachers’ intention to use mobile augmented reality in their future teaching. A proposed Mobile Augmented Reality Acceptance Model (MARAM) was developed from previous TAM studies to guide research.

For the study’s first aim, the results show that intention was affected by pre-service and in-service teachers’ attitude toward the use of MAR as well as perceived usefulness. This finding supports previously documented acceptance of digital technologies (Scherer & Teo, 2019) and mobile augmented reality studies (Asiri & El-Aasar, 2022; Cabero-Almenara et al., 2019; Ma et al., 2021) which found that perceived usefulness and attitudes had a positive effect on intention. In essence, when pre-service and in-service teachers perceive MAR as useful in their teaching and have positive atti-

Table 11 Measurement invariance test using MICOM for models with the FC component

Constructs	H0: Compositional measurement invariance of the constructs (ii)			H0: Difference between group means is zero			H0: Log of the ratio of the group variances is zero			Measurement Invariance
	C-value	p-value	Compositional invariance?	Mean original difference	p-value	Equal mean?	Logarithm of the composite's variances ratio	p-value	Equal variances?	
PE	0.9997	0.1650	Yes	0.4373	< 0.001	No	-0.4773	0.0060	No	Partial
PRA	0.9982	0.2153	Yes	0.0786	0.5371	Yes	-0.2180	0.2164	Yes	Full
MSE	0.9992	0.5332	Yes	0.3234	< 0.001	No	-0.1987	0.2445	Yes	Partial
FC	0.9708	< 0.001	No	-	-	-	-	-	-	-
PEOU	0.9994	0.0543	Yes	0.4938	< 0.001	No	-0.1206	0.4569	Yes	Partial
PU	0.9998	0.2354	Yes	0.1473	0.2425	Yes	-0.3706	0.0541	Yes	Full
Attitude	0.9997	0.2133	Yes	0.4946	< 0.001	No	-0.4901	< 0.001	No	Partial
Intention	0.9984	0.1569	Yes	0.4370	0.0020	No	-0.2967	0.0581	Yes	Partial

Table 12 Assessment of group differences with the FC component

Path	Coefficient (95% C.I.) in-service	Coefficient (95% C.I.) pre-service	Overlap	p-value Henseler's
PEOU → PU	0.050 (-0.121, 0.211)	0.002 (-0.190, 0.229)	Yes	0.340
PEOU → Att	0.067 (-0.115, 0.221)	0.097 (-0.071, 0.295)	Yes	0.594
PU → Att	0.244 (0.039, 0.480)	0.404 (0.207, 0.594)	Yes	0.866
PU → I	0.234 (0.022, 0.478)	0.344 (0.202, 0.509)	Yes	0.797
Att → I	0.422 (0.149, 0.744)	0.503 (0.259, 0.669)	Yes	0.688
FC → PEOU	**0.528 (0.178, 0.755)**	**0.580 (0.379, 0.803)**	**Yes**	**0.600**
FC → I	**0.367 (0.110, 0.572)**	**0.106 (-0.054, 0.281)**	**Yes**	**0.036**
PRA → PU	0.372 (0.232, 0.494)	0.451 (0.247, 0.613)	Yes	0.767
PE → Att	0.628 (0.376, 0.860)	0.381 (0.134, 0.607)	Yes	0.069
PE → PU	0.518 (0.364, 0.702)	0.368 (0.160, 0.546)	Yes	0.121
MSE → PEOU	0.450 (0.225, 0.757)	0.337 (0.109, 0.546)	Yes	0.264

Bold: Results not to be taken into consideration, since we excluded FC component

tudes towards it, they will also show greater positive intention to use this immersive technology. Moreover, pre-service and in-service teachers' attitudes toward the use of MAR was affected by perceived usefulness and perceived enjoyment. These findings are also supported by previous studies investigating the acceptance of technologies (Lee et al., 2019; Swani, 2021; Teo & Noyes, 2011). This means that both samples of teachers show a positive attitude because they consider MAR enjoyable and useful in their teaching. Similar findings for perceived usefulness (Asiri & El-Aasar, 2022; Rahmat & Mohamad, 2021) and perceived enjoyment (Cabero-Almenara et al., 2019) have also been found in previous MAR acceptance studies.

Furthermore, perceived usefulness in both samples was affected by perceived enjoyment and perceived relative advantage. This result is overall consistent with recent studies on the importance of the role of perceived relative advantage in technology acceptance models in education (Al-Rahmi et al., 2019, 2021; Alyoussef, 2022). This finding shows that for MAR to be utilized in teaching in the future, educators need to perceive that this technology has more advantages compared to other technologies they currently use.

Another result emerging from this study relates to the role played by facilitating conditions. This component in the total sample affected intention which reinforces the significance of the role of facilitating conditions (e.g., availability of computers, time, training) as indicated in previous acceptance models, in encouraging the use of

Table 13 Measurement invariance test using MICOM for models without the FC component

Constructs	H0: Compositional measurement invariance of the constructs (ii)			H0: Difference between group means is zero			H0: Log of the ratio of the group variances is zero			Measurement Invariance
	C-value	p-value	Compositional invariance?	Mean original difference	p-value	Equal mean?	Logarithm of the composite's variances ratio	p-value	Equal variances?	
PE	0.9997	0.1633	Yes	0.4373	< 0.001	No	-0.4773	0.0060	No	Partial
PRA	0.9982	0.2157	Yes	0.0786	0.5371	Yes	-0.2180	0.2164	Yes	Full
MSE	0.9992	0.5363	Yes	0.3234	< 0.001	No	-0.1987	0.2445	Yes	Partial
PEOU	0.9994	0.0665	Yes	0.4934	< 0.001	No	-0.1202	0.4589	Yes	Partial
PU	0.9998	0.2379	Yes	0.1473	0.2425	Yes	-0.3706	0.0541	Yes	Full
Attitude	0.9997	0.2218	Yes	0.4947	< 0.001	No	-0.4901	< 0.001	No	Partial
Intention	0.9978	0.0806	Yes	0.4395	0.0020	No	-0.3010	0.0521	Yes	Partial

Table 14 Assessment of group differences without the FC component

Path	Coefficient (95% C.I.) in-service	Coefficient (95% C.I.) pre-service	Overlap	p-value Henseler's
PEOU → PU	0.050 (-0.137, 0.226)	0.003 (-0.217, 0.207)	Yes	0.370
PEOU → Att	0.068 (-0.129, 0.228)	0.098 (-0.070, 0.268)	Yes	0.590
PU → Att	0.244 (0.021, 0.450)	0.404 (0.217, 0.589)	Yes	0.871
PU → I	0.282 (0.001, 0.515)	0.356 (0.230, 0.507)	Yes	0.674
Att → I	0.623 (0.396, 0.888)	0.552 (0.362, 0.701)	Yes	0.335
PRA → PU	0.372 (0.250, 0.519)	0.450 (0.280, 0.628)	Yes	0.751
PE → Att	0.627 (0.389, 0.899)	0.381 (0.101, 0.576)	Yes	0.076
PE → PU	0.518 (0.340, 0.691)	0.368 (0.180, 0.586)	Yes	0.125
MSE → PEOU	0.869 (0.787, 0.937)	0.719 (0.598, 0.835)	Yes	0.016

technology in schools (Huang et al., 2021; Mukminin et al., 2023; Songkram et al., 2023). Regarding the sample of pre-service teachers, facilitating conditions were not shown to impact their intention. This may be explained by pre-service teachers' lack of experience or awareness of the role of factors that facilitate the use of digital technology in schools. The absence of any significant effect of facilitating conditions on pre-service teachers' intention is consistent with the empirical results of Teo (2012), but inconsistent with the findings of Teo et al. (2019) and Gurer (2021).

It is interesting to note that perceived ease of use had no effect on attitude or perceived usefulness. This means that pre-service and in-service teachers adopt positive attitudes and perceptions on the usefulness of MAR regardless of whether they consider it to be easy to use. This finding contradicts a previous study which found that perceived ease of use has a positive effect on the perceived usefulness of MAR (Ibili et al., 2019). On the contrary, perceived ease of use, both for the total sample, as well as the sample of pre-service teachers, was influenced by facilitating conditions. This result implies that the more facilitating conditions offered to teachers enabling the use of MAR in their schools, the easier they may find it to use MAR in their teaching. Similar results regarding the positive effect of facilitating conditions on perceived ease of use were also found in recent studies (Huang et al., 2021; Mukminin et al., 2023; Songkram et al., 2023). Finally, the results for all samples showed that perceived ease of use was affected by mobile self-efficacy. Recent studies by Mensah (2022) and Song et al. (2022) also concluded that mobile self-efficacy has a significant effect on perceived ease of use. This finding suggests that when pre-service and in-service teachers possess experience and self-efficacy in their use of applications on mobile devices, they will perceive the use of MAR to be easier.

For the second aim of this study, findings show that the MARAM is a valid model and could be used to investigate intention among pre-service and in-service teachers.

To the best of our knowledge, this is the first study to investigate an acceptance model on two teacher samples, as well as comprehensively, for the purpose of determining their intentions. As Table 9 shows, compared to other technology acceptance models (Scherer & Teo, 2019; Scherer et al., 2019), the MARAM can explain the substantial degree of variance among perceived ease of use, perceived usefulness, attitude, and intention. All the hypotheses in this study were confirmed, except for those on the effect of perceived ease of use and facilitating conditions; most likely for the reasons mentioned above. This finding also serves as a motive to conduct further research to investigate the effect of these two components on different samples. Finally, compared to the other acceptance models in Table 2 used with pre-service and in-service teachers, the MARAM included the components of perceived relative advantage and mobile self-efficacy to examine the acceptance of MAR for the first time, and the results were encouraging.

6.1 Implications

These findings have specific implications for the future use of MAR in schools. To foster positive and strong intentions among pre-service and in-service teachers to use MAR in their teaching, it is important that schools and universities help them develop positive attitudes toward its use. This could be achieved if they believe that, aside from being enjoyable, MAR is also useful in their teaching, and more specifically, it provides advantages both to them, as well as to their students. They must be convinced that this technology has affordances and pedagogical-added value compared to other technologies. As seen in a previous section, such affordances include the combination of digital and physical objects in a real environment (Dunleavy et al., 2009), the concretization and representation of invisible, complex, and abstract concepts (Akçayır & Akçayır, 2017; Bujak et al., 2013), and the real-time interaction with real and virtual objects (Azuma, 1997; Zhou et al., 2022). Therefore, the development of positive intentions and attitudes toward the use of MAR could begin at the time of teachers' undergraduate studies, by adding courses in their curriculum that are relevant to mobile learning and augmented reality. This could focus not only on the technological training of future teachers, but primarily, on the pedagogical design of MAR applications. In addition, schools should be equipped with the necessary infrastructure and resources (e.g., mobile devices and internet connection), as well as provide all the necessary conditions (e.g., time for teachers to prepare their lessons) to ensure that teachers can use MAR seamlessly. A recent study on MAR in education has shown that support from the school community and the capability to train teachers can contribute to this (Koutromanos & Jimoyiannis, 2023). Moreover, considering that most applications are commercially available but costly in terms of their wider use in education (Arici et al., 2021; Ajit, 2021), both the research and teaching community, in conjunction with private institutions and companies, must invest in the development of new and easy to use open-source MAR applications.

The study has several implications for researchers also. Firstly, the MARAM model can serve as a basis to promote future research. It is interesting that both components of the original TAM – perceived usefulness and attitudes toward MAR – remain strong predictors of intention. Secondly, this is the first time where perceived relative advantage was used in a MAR technology acceptance model. As mentioned earlier, perceived relative advantage is a component that measures teachers' perceptions on the advantages of using MAR in teaching compared to other digital technologies. Its use in the MARAM enhances the argument for MAR's perceived usefulness. Thirdly, it is interesting to note that the component of mobile self-efficacy affects perceived ease of use. Therefore, this proposed component can be used in the future in other MAR technology acceptance models as well. On the contrary, there are concerns regarding the component of perceived ease of use because it did not appear to affect pre-service or in-service teachers' perceived usefulness and attitudes. Considering that the sample of this study possessed knowledge of MAR on a methodological level, further study is needed to determine whether this component is more important for novice MAR users. Fourthly, further study is required on the role of facilitating conditions. As we have seen, this component had a relatively low Cronbach a in its internal consistency. Furthermore, for reasons already mentioned, this component was excluded from the statistical analysis of the MARAM for the sample of in-service teachers, seeing as the existing items for this component may not adequately measure the conditions that facilitate the use of MAR in schools. Another possible reason is that the teachers in this study have been trained in a centralized educational system, where the factors that reinforce the use of a digital technology do not depend exclusively on them, but on the Ministry of Education and the institutions it oversees. Consequently, future research could also examine the degree to which facilitating conditions affect pre-service and in-service teachers trained in different educational systems.

6.2 Limitations and future work

This study included a sample of pre-service and in-service teachers who were given information on the affordances of MAR, interacted with MAR applications, and developed their own augmented material for various subjects. Therefore, the results cannot be generalized for other pre-service and in-service teachers who are not familiar with MAR. Another limitation is that the sample of this study did not have the opportunity to use the augmentations they created in real learning situations with students. This limitation means that the findings of our study may be different for teachers who are already applying MAR in their teaching.

Aside from the aforementioned limitations, future studies could investigate whether there are other external variables (e.g., gender, ICT skills) or psychological factors that affect pre-service and in-service teachers' intentions, which could improve the predictive power of the MARAM. Next, future research could also compare the results of the current study with samples of pre-service teachers and in-service teachers from specific disciplines (e.g., mathematics teachers, science teachers) or other levels of education (e.g., primary, secondary) to examine if significant differences exist and whether the MARAM remains a valid and generalizable model. Finally, future studies could examine the degree to which the MARAM model is appropriate for observing MAR with AR glasses, which provide a greater immersive experience compared to mobile devices (i.e., smartphones and tablets).

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Data Availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

Ethics approval All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. The authors have no financial or proprietary interests in any material discussed in this article.

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