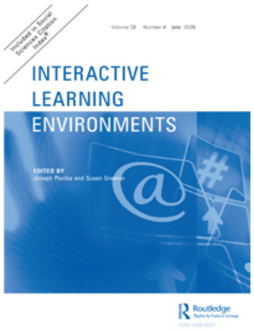

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Augmented reality in preschool settings: a cross-sectional study on adoption dynamics among educators

Ayşegül Şakir

Department of Preschool Education, Kırşehir Ahi Evran University, Kırşehir, Turkey

ABSTRACT

Augmented Reality (AR) offers transformative, immersive learning experiences in preschool education. However, its successful adoption largely depends on educators' willingness to integrate this technology. This study investigates AR adoption in preschool education by combining the Technology Acceptance Model (TAM), Flow Theory, and Theory of Planned Behavior (TPB) into a unified framework. Data from 1050 pre-service and in-service preschool teachers across Turkey were analyzed using Structural Equation Modeling. Results indicate a significant positive correlation between educators' perceptions of AR's usefulness, ease of use, and their intent to adopt it. Intrinsic motivational factors, such as perceived enjoyment and concentration, also played key roles in influencing behavioral intentions towards AR. Our unified model provides a deeper understanding of the determinants impacting teachers' intentions to use AR in preschool settings, compared to existing theories. This research offers actionable insights for educators, curriculum designers, and policymakers to harness AR's potential in early childhood education, aiming to provide engaging and effective learning experiences for young children.

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KEYWORDS
Pre-school education; augmented reality; in-service teachers; pre-service teachers; unified conceptual framework

1. Introduction

The rapid advancement of technology has profoundly transformed various sectors, including education, by introducing innovative tools that redefine traditional learning environments. Specifically, in preschool education, augmented reality (AR) has emerged as an invaluable tool, promising to enhance learning experiences through its interactive and immersive capabilities (Kayaduman & Sağlam, 2024). AR blends digital information with the real world in real-time, allowing young learners to engage with educational content in a manner that is both captivating and accessible (Dargan et al., 2023). Integrating AR in preschool settings extends beyond visual stimulation; it actively involves young learners in their educational journey, making learning an interactive, fun, and participatory experience (Polyzou et al., 2023). For instance, AR can animate storybooks, turning reading sessions into dynamic and interactive adventures where characters and environments leap off the pages (Donally, 2022). It can also introduce young children to concepts like shapes, colors, numbers, and the natural world in a highly interactive manner that encourages exploration and discovery (Dalim et al., 2020). The use of AR promotes experiential learning, where preschoolers can see and interact with three-dimensional objects from various angles, fostering their spatial awareness and cognitive development (Meister et al., 2022). This hands-on approach is particularly effective in early education, as it aligns with the developmental needs and learning styles of young children, who learn best through play and direct interaction with their environment. Moreover, AR supports

CONTACT Ayşegül Şakir aselimhocaoglu@ahievran.edu.tr

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collaborative learning among young children, encouraging them to work together and communicate as they explore AR scenarios (Alhumaidan et al., 2015). This not only enhances their social skills but also teaches them how to express their ideas and solve problems collectively. For educators, AR offers versatile teaching tools that can be adapted to individual learning needs, allowing for personalized educational experiences that cater to the varied learning speeds and styles of preschool children (Aydoğdu, 2022). As AR technology becomes more accessible and affordable, its integration into preschool classrooms is increasingly feasible, offering a powerful means to democratize advanced educational tools across diverse learning settings (Criollo et al., 2024). This shift holds the potential to significantly elevate the quality of early childhood education, ensuring that young learners receive stimulating, engaging, and effective educational experiences that set a strong foundation for their lifelong learning journey.

The integration of advanced technologies such as AR into preschool education presents a transformative opportunity, promising to enhance the teaching and learning experience through its interactive and immersive capabilities (Oranç & Küntay, 2019). Despite these potential benefits, the adoption rates among educators vary significantly, influenced by several complex factors that this study seeks to explore. Understanding these factors is crucial, as they can affect the successful integration of AR technologies into educational settings, thereby shaping the future of teaching and learning strategies. To comprehensively address these adoption disparities, our research employs a multidimensional approach by integrating the Technology Acceptance Model (TAM), Flow Theory, and the Theory of Planned Behavior (TPB). The role of the Technology Acceptance Model (TAM), Flow Theory, and the Theory of Planned Behavior (TPB) in understanding AR adoption among educators is crucial, as each theory offers distinct yet complementary perspectives that enhance our understanding of technology integration in educational settings (Ateş & Garzón, 2022). The TAM serves as a foundational framework in technology adoption studies. It posits that perceived ease of use and perceived usefulness are critical determinants of technology acceptance (Davis, 1989). In the context of AR, if teachers perceive AR technologies as easy to use and believe that they will enhance the learning outcomes, their likelihood of adopting these technologies increases (Jang et al., 2021). The TAM helps to quantify these perceptions and their impact on decision-making processes, providing a clear metric for evaluating the effectiveness of AR interventions in educational environments (Ibili et al., 2019). Building on the insights provided by the TAM, Flow Theory offers a deeper exploration of the psychological states experienced by users when interacting with technology (Lu et al., 2009). This theory is particularly relevant to AR due to its immersive nature. Flow Theory can examine how AR can create a learning environment that captivates educators' attention completely and provides a seamless experience that can lead to higher levels of engagement and satisfaction. By understanding the conditions that facilitate such deep immersion, educators can better design and implement AR experiences that are not only educational but also inherently rewarding and motivating for both teachers and students (Ziden et al., 2022). On the other hand, the TPB adds an additional layer of analysis by considering the social and psychological components of technology adoption. It emphasizes that an individual's behavioral intentions are influenced not only by personal attitudes but also by subjective norms and perceived behavioral control. In educational settings, this means that the intentions of educators to use AR technologies are shaped by the societal expectations and pressures from peers and administration, as well as by their own confidence in their ability to effectively use these technologies (Ateş & Garzón, 2023). TPB helps to identify specific barriers and enablers in the social and institutional context, which can be crucial for developing strategies to support educators in the adoption process (Scannell et al., 2020). Integrating these three models provides a comprehensive framework for examining the multifaceted nature of technology adoption. This holistic approach not only underscores the importance of individual and contextual factors in shaping technological integration but also highlights the interplay between human cognition, the social environment, and the technological attributes of AR. Understanding these dynamics is essential for devising effective interventions that can enhance the acceptance and sustained use of AR in educational contexts, ultimately leading to more engaging and effective teaching and learning strategies.

Previous studies conducted on teacher adoption have predominantly focused on mobile devices and digital tools in preschool education (e.g. Hong et al., 2021; Rad et al., 2022) but have not specifically addressed the unique context of AR use among preschool educators. This oversight leaves a notable gap in understanding how augmented reality can be tailored and implemented in early childhood learning environments. By exploring this under-researched area, this study aims to fill a significant gap in the literature and contribute to a better understanding of how early childhood educators perceive and interact with advanced technological tools. This study, therefore, not only investigates the technical feasibility of AR in preschool settings but also delves into the psychological and socio-cultural factors that influence educators' decisions to adopt such technologies. The results are expected to offer valuable insights into the effective integration of AR in preschool environments, highlighting critical factors such as ease of use, educational value, and the support needed for educators to successfully adopt and utilize AR in their teaching practices. Furthermore, the findings will have broader implications for educational policymakers, curriculum developers, and technology designers. These stakeholders can use the insights gained to promote more widespread and effective use of AR in education, ensuring that these tools meet the specific needs of early childhood education and are implemented in ways that enhance learning outcomes. By providing a detailed analysis of these aspects, the study aims to equip educational stakeholders with the knowledge to create environments where both teachers and students can benefit from the promises of AR technology. The ultimate goal is to foster an educational landscape that is not only technologically advanced but also pedagogically sound and aligned with the developmental needs of preschool children. This approach will help to ensure that the integration of new technologies like AR into educational settings is both thoughtful and effective, paving the way for future innovations in teaching and learning strategies.

2. Literature review

2.1. Overview of augmented reality in education

AR represents a significant advancement in educational technology, offering a dynamic blend of the real-world environment with enhanced, interactive digital elements (Dargan et al., 2023; Kayaduman & Sağlam, 2024). This technology has shown great potential to transform traditional educational methods by introducing a layer of digital information to the learning space that is both engaging and interactive (Ateş, 2024; Gong et al., 2022). AR in education enables the overlay of text, images, and videos onto the physical world, providing a unique visual and experiential learning experience that can make educational content more accessible and appealing (Lin et al., 2016). For example, in science classes, AR can bring diagrams of complex cellular structures to life, allowing students to explore them in three dimensions (Yildirim, 2020). In history lessons, AR can recreate historical events or bring extinct civilizations back to life, offering students a virtual window into the past (Remolar et al., 2021). The implementation of AR in educational settings has been supported by various studies that highlight its benefits in increasing student engagement and motivation (e.g. Georgiou & Kyza, 2018). AR applications have been shown to transform passive learning scenarios into interactive sessions where students can manipulate and interact with 3D models, leading to improved understanding and retention of information. Furthermore, AR encourages active learning and participation, catering to diverse learning styles and needs. Beyond individual learning, AR also fosters collaboration among students (Jesionkowska et al., 2020). By sharing AR experiences, students can work together in an enhanced reality that promotes communication and teamwork (Toriz García et al., 2022). This is particularly beneficial in projects that require collective problem-solving and innovation (Cabero-Almenara et al., 2021; Karagozlu, 2018).

However, the deployment of AR in education is not without challenges. It requires adequate technological infrastructure and access to compatible devices, which can be a significant barrier in under-resourced schools (Alzahrani, 2020). Additionally, educators need proper training to effectively integrate AR tools into their teaching strategies (Barsom et al., 2016). Despite these challenges, the potential of AR to enhance educational outcomes remains clear (Christopoulos et al., 2022). Its ability to merge digital content with the physical world offers an innovative avenue for curriculum delivery that resonates with today's tech-savvy generation. As technology advances and becomes more accessible, AR could play a pivotal role in shaping future educational practices, making learning more engaging, interactive, and effective (Yuen et al., 2011).

2.2. The impact of AR on early childhood education

Recognizing the critical period of early childhood and the importance of providing enriching educational experiences during this time, AR is transforming early childhood education by integrating digital elements with the real world, creating engaging and interactive learning experiences that are well suited to young learners (Gong et al., 2022; Kayaduman & Sağlam, 2024; Oranç & Küntay, 2019). Early childhood is a crucial phase for cognitive, social, and emotional development, and AR's ability to create immersive and interactive environments contributes significantly to these developmental areas.

For instance, a detailed case study of a preschool in Istanbul illustrates how AR was used to animate storybooks, where characters and environments leapt off the pages in three dimensions (Kocak & Goktas, 2021; Kuek, 2020). This approach not only captured the children's attention but also significantly enhanced their engagement and motivation (Georgiou & Kyza, 2018), fostering a love for reading and encouraging active participation in storytime activities. Teachers reported that children were more excited and focused during AR-enhanced sessions compared to traditional methods (Aydoğdu, 2022).

By making learning more dynamic and interactive, AR helps build foundational skills in a manner that is both enjoyable and effective, setting a strong educational foundation for future learning. The use of AR in preschool settings supports experiential learning, allowing children to interact with virtual objects and scenarios. In another example, an AR application was used in a preschool science lesson to explore the lifecycle of a butterfly (Tarng et al., 2015). Children could observe the metamorphosis process in an interactive, hands-on manner that traditional teaching tools could not provide. This direct interaction with complex concepts helped solidify cognitive development and reinforced learning through active participation (Bujak et al., 2013; Dunleavy et al., 2009; Yilmaz, 2016).

Moreover, AR aids in language acquisition and cognitive growth by providing multisensory learning experiences that combine sounds, images, and text. This method helps in teaching vocabulary, pronunciation, and basic literacy skills, enhancing retention and recall of information (Yilmaz, 2016). Additionally, AR fosters social interaction and collaboration among young learners. Many AR applications are designed for group activities that encourage children to work together, enhancing social skills such as communication, turn-taking, and empathy (Billinghurst & Duenser, 2012; Cheng & Tsai, 2013). For example, a group-based AR activity in a classroom setting was shown to improve children's communication skills as they navigated a virtual treasure hunt together, negotiating roles and sharing discoveries, which in turn enhanced their social bonds (Mukkawar & Netak, 2021).

Personalization of learning experiences is another significant advantage of AR (Marienko et al., 2020). It can adjust the difficulty level of tasks based on the user's interaction, allowing for customized learning that caters to the individual strengths and weaknesses of each child. Despite these benefits, the integration of AR into early childhood education faces challenges (Tuli & Mantri, 2021), including the need for adequate training for educators, ensuring age-appropriate content, and addressing the digital divide to ensure equitable access to technology.

Overall, AR offers promising enhancements to early childhood education by making learning more engaging, interactive, and personalized. Its ability to bring abstract concepts to life and foster immersive learning environments supports the developmental needs of preschool-aged children (Dunleavy et al., 2009; Yilmaz, 2016). As AR technology continues to evolve, its impact on early childhood education is expected to grow. Future studies could include more comprehensive case studies and visual data presentations to further illustrate AR's transformative potential, potentially reshaping traditional educational methods and setting new standards for interactive learning (Wu et al., 2013). Table 1 provides a clear and organized way to present the key aspects of AR adoption in preschool education, making it easier for readers to understand the process and its implications.

2.3. The research model and hypotheses

2.3.1. Technology acceptance model

The TAM provides a robust framework for understanding the adoption of technologies like AR in educational settings. Central to TAM are the constructs of perceived ease of use and perceived usefulness, which are pivotal in shaping educators' attitudes and behavioral intentions towards technology (Chocarro et al., 2023). In the context of preschool education, where AR can significantly enhance the learning experience through interactive and immersive methods, understanding these perceptions becomes crucial (Kayaduman & Sağlam, 2024: Zhufeng & Sitthiworachart, 2024).

Firstly, the ease with which educators can use AR technology influences their perception of its usefulness. If AR tools are user-friendly and straightforward, teachers are more likely to view them as beneficial for teaching and learning. This relationship suggests that simplifying the user interface and reducing the complexity of AR applications can enhance their perceived utility, making them more attractive to educators who may not have extensive technical backgrounds. For example, a study by Papakostas et al. (2023) found that ease of use significantly predicted the usefulness of AR tools in educational settings, underlining the importance of user-friendly design in educational technology.

Table 1. Key stages and findings in the adoption process of augmented reality (AR) in preschool education.

Stage	Description	Key Findings	Challenges	Strategies for Success
Awareness	Initial exposure to AR technology, including understanding its potential in educational settings.	AR has the potential to enhance engagement and learning outcomes in preschool education.	Limited awareness among educators and stakeholders about the benefits and applications of AR.	Provide workshops, seminars, and demonstrations to increase awareness and understanding of AR technology.
Training	Providing educators with the necessary skills and knowledge to effectively use AR tools in their teaching practices.	Educators who receive proper training are more likely to integrate AR successfully.	Insufficient training programs and resources for educators to learn how to use AR technology effectively.	Develop comprehensive training programs that include hands-on practice with AR tools.
Implementation	The practical application of AR in classroom settings, where educators begin using the technology with their students.	Early adoption shows positive results in student engagement and interactive learning experiences.	Technical difficulties, lack of support, and resistance to change from traditional teaching methods.	Offer continuous technical support and create a supportive community among educators using AR.
Integration	Full integration of AR into the curriculum, where it becomes a regular part of the educational experience in preschool settings.	AR becomes a valuable tool that enhances the overall educational experience, promoting active learning.	Difficulty in aligning AR content with the curriculum and maintaining long-term usage among educators.	Ensure AR content is aligned with educational goals and provide ongoing support to sustain its usage.

Moreover, the ease of using AR also impacts teachers' attitudes towards its adoption. When technology is easy to use, it tends to elicit a more favorable response. Educators who find AR tools straightforward and hassle-free are likely to have a positive attitude towards using these tools in their teaching practices. This positive attitude is vital as it lays the foundation for the actual usage of technology in classrooms. Casey et al. (2023) reported that educators' positive attitudes towards AR were strongly influenced by the simplicity and intuitiveness of the technology.

Perceived usefulness, another cornerstone of TAM, also plays a significant role in influencing educators' attitudes. When teachers perceive AR as a tool that can improve educational outcomes – for instance, by making classes more engaging and informative – their overall attitude towards adopting such technology improves. This perception is critical because it directly impacts their intention to use AR. The belief that AR can lead to better educational results motivates teachers to integrate it into their teaching methodologies. Ateş and Garzón (2023) demonstrated that perceived usefulness was a strong predictor of teachers' willingness to adopt AR technologies.

Finally, the intention to use AR is heavily influenced by its perceived usefulness. Educators' decisions to adopt AR are bolstered by their belief in the technology's capability to enhance learning. If AR is seen as a tool that can provide significant educational benefits, such as increasing student engagement or improving understanding of complex concepts, teachers are more likely to be inclined towards its usage. In a recent study, Ateş and Garzón (2023) found that the perceived usefulness of AR had a direct and significant impact on teachers' intentions to implement it in their classrooms.

Collectively, these dynamics underscore the importance of both perceived ease of use and usefulness as essential drivers of AR adoption in preschool settings. By leveraging TAM, stakeholders in educational technology can gain insights into the factors that encourage or hinder the adoption of AR among preschool educators, enabling them to design interventions that address these factors and facilitate smoother integration of AR into educational practices. Based on the preceding discussion, the following hypotheses are formulated.

H1: Perceived ease of use will have a positive influence on the perceived usefulness of AR technologies among preschool educators.

H2: Perceived ease of use of AR technologies will positively influence preschool educators' attitudes towards their usage.

H3: Perceived usefulness of AR technologies will positively influence preschool educators' attitudes towards their adoption.

H4: Perceived usefulness of AR technologies will positively influence preschool educators' intention to use them.

2.3.2. Flow theory

Flow Theory, conceptualized by Csikszentmihalyi, elucidates the mechanisms through which deep immersion and engagement, facilitated by technologies such as AR, significantly enhance the educational environment, particularly within preschool settings (dos Santos et al., 2018). This theoretical framework articulates the psychological impacts of perceived enjoyment and concentration on educators' attitudes towards, and intentions to integrate, AR into their teaching practices.

When educators find AR enjoyable, it enhances their attitude toward incorporating this technology into their teaching methods and significantly influences their intention to continue its use (Jang et al., 2021). The intrinsic joy derived from engaging with AR technologies makes routine educational activities more stimulating and engaging. Studies by Ateş and Garzón (2022) have demonstrated a strong correlation between the enjoyment of digital tools and positive attitudes toward their adoption in educational settings. Similarly, Tseng et al. (2022) found that the pleasure educators derive from using interactive technologies strongly predicts their continued use, highlighting a critical factor in technology adoption.

Furthermore, the level of concentration or immersion that educators experience while using AR plays a crucial role in shaping their attitudes and intentions. High levels of engagement, indicating deep immersion, foster a positive disposition towards technology, as noted by Liu et al. (2009), who highlighted the direct correlation between concentration levels and positive attitudes toward technology use in education. This deep engagement also translates into a higher likelihood of continued use, as detailed by An et al. (2024), who found that educators' intentions to adopt new technologies are greatly influenced by their level of immersion during initial interactions.

Thus, we suppose that applying Flow Theory to the context of AR in preschool education provides significant insights into the psychological experiences that influence educators' behaviors toward technology adoption. By enhancing both the enjoyment and the immersive quality of AR, technology developers and educational policymakers can foster more widespread acceptance and integration of these tools in educational settings. Drawing from the discussions outlined above, we propose the subsequent hypotheses.

H5: Perceived enjoyment significantly enhances educators' attitudes towards using AR technology in preschool settings.

H6: Perceived enjoyment significantly increases preschool educators' intentions to incorporate AR technology into their teaching practices.

H7: High levels of concentration significantly improve preschool educators' attitudes towards using AR technology.

H8: High levels of concentration significantly boost preschool educators' intentions to adopt and utilize AR technology in their classrooms.

2.3.3. Theory of planned behavior

The TPB is pivotal in understanding the behavioral intentions of individuals across various contexts, including the adoption of AR technologies in teacher education (Ateş & Garzón, 2022). This theory posits that an individual's behavior is directly influenced by their intention to perform the behavior, which is shaped by their attitudes towards the behavior, subjective norms, and perceived behavioral control (Ajzen, 1991).

In the context of AR adoption among preschool educators, three factors are particularly crucial in determining their intentions to use AR technologies: attitudes towards using AR, the influence of significant others or subjective norms, and educators' perceived control over the use of AR (Chan, 2020). A positive attitude towards AR indicates that educators recognize the benefits of using AR, which is likely to enhance their intention to incorporate it into their teaching practices (Faqih & Jaradat, 2021). Subjective norms, or the perceived social pressure to engage or not engage in using AR, also play a significant role. If influential people within an educator's professional circle, such as colleagues or education leaders, view the use of AR favorably, the educator is more likely to adopt AR themselves (Jang et al., 2021). This influence is supported by findings from a study by Saleem et al. (2023), which highlighted that peer influence significantly impacts teachers' decisions to integrate AR technologies into their classrooms. Furthermore, perceived behavioral control, which reflects an educator's perception of the ease or difficulty of using AR, critically affects their intention to use it (Ateş & Garzón, 2023). Educators who feel confident in their ability to operate AR technologies and perceive fewer obstacles in their use are more likely to adopt them. This relationship was underscored by Koutromanos and Mavromatidou (2021), who found that teachers' perceptions of their ability to manage technology effectively led to a greater intention to implement it in their teaching.

Thus, we suppose that the application of TPB in this context not only aids in understanding the factors influencing AR adoption among preschool educators but also provides a framework for developing strategies to encourage its uptake. By addressing these key psychological factors, education technology developers and policymakers can better support educators in the integration of

AR, potentially enhancing educational outcomes in preschool settings. The discussions above lead to the formulation of the following hypotheses:

> **H9:** Attitudes towards using AR have a positive impact on the intention to integrate AR technologies in preschool educational settings.

> **H10:** Subjective norms, encompassing perceived social pressures, positively influence the intention to adopt AR technologies in preschool teaching practices.

> **H11:** Perceived behavioral control significantly enhances the intention to utilize AR technologies in preschool classrooms.

Consequently, this study centers on the adoption determinants and engagement drivers that influence preschool teachers' acceptance of AR technologies. The primary aim of our research is to propose a model that combines the TAM, Flow Theory, and TPB to predict teachers' behavioral intentions to use AR in preschool settings (see Figure 1). Specifically, the objectives set for this study are:

1. Propose a model that provides an understanding of preschool teachers' intentions to use AR by integrating TAM, Flow Theory, and TPB into a comprehensive research model. This model will also compare the explanatory power of each theory individually, as well as the combined model, in explaining intentions to use AR.
2. Test the relative importance among the variables in the proposed model to understand preschool teachers' intentions to use AR. This includes investigating the mediating roles of perceived usefulness and attitude towards the adoption of AR technologies.
3. Examine the moderating effects of sample type (pre-service and in-service preschool teachers) within the proposed conceptual model, to discern how these factors may influence AR adoption differently across various teacher demographics.

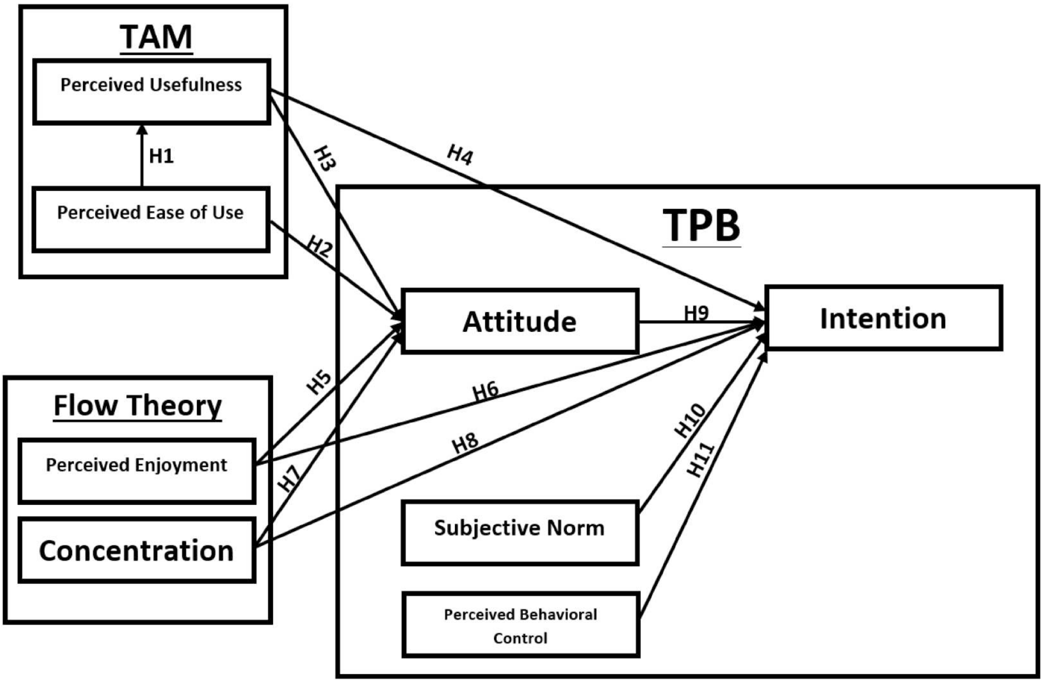

Figure 1. Conceptual model.

3. Method

3.1. Data collection process

The data collection process began with an initial workshop that introduced these educators to AR technologies. This session focused on the educational benefits, usability, and potential enhancements to preschool education that AR offers. Demonstrations of AR applications and their alignment with educational goals were highlighted, accompanied by hands-on training sessions. These practical experiences were vital for teachers to grasp the technology's utility in real teaching scenarios. Following the introductory phase, a technical orientation was provided, detailing the AR system's requirements, including hardware and software specifics, along with setup instructions and available educational content. Comprehensive user manuals and visual aids such as diagrams and video tutorials were prepared to guide educators through the setup and usage of the AR tools. To assess the immersive and engaging qualities of AR, structured AR sessions were organized where both in-service and pre-service teachers used the tools in simulated preschool environments. These sessions were designed to allow teachers to achieve a state of flow, thereby enhancing their engagement with the technology. Subsequent focus group discussions explored educators' experiences, particularly focusing on aspects of flow and engagement facilitated by AR. Behavioral intentions and usage patterns were further analyzed through surveys and interviews based on the TPB framework. These instruments assessed educators' attitudes, subjective norms, and perceived behavioral control over using AR in their teaching. Observational studies complemented these methods by providing insights into how teachers planned and integrated AR into their lesson planning and teaching execution. A robust support system was also established, including a help desk, online forums, and regular Q&A sessions to assist educators with any technical issues. A structured feedback mechanism was implemented, utilizing regular surveys, focus groups, and informal feedback during training sessions to assess user satisfaction and identify areas for improvement. The study also documented success stories and case studies that highlighted effective uses of AR in preschool education. These narratives served both as motivational resources and practical examples for educators considering the adoption of AR technologies. Finally, the project ensured continuous improvement through regular updates on advancements and changes in AR technology. All documentation and training materials were regularly revised to reflect the latest developments and best practices, ensuring the AR tools remained relevant and effective in educational settings. This comprehensive data collection process aimed to provide a deep understanding of the factors influencing the adoption of AR and its impact on educational outcomes, informed by TAM, Flow Theory, and TPB, for both in-service and pre-service teachers.

3.2. Participants

The study employed a cross-sectional design, utilizing an online survey distributed from October 2023 to May 2024, aligned with the academic year. Participants comprised a diverse group of in-service and pre-service teachers selected through purposive sampling from multiple educational institutions across Turkey. Specifically, the survey targeted pre-service teachers predominantly enrolled in preschool education programs at well-known universities. Prior to survey distribution, all participants were required to sign informed consent forms that detailed the study's objectives, their potential contributions, and the voluntary nature of their participation, ensuring adherence to ethical standards. This process guaranteed informed and voluntary engagement, crucial for the integrity of the study. The survey achieved a high engagement level, with a total of 1050 responses, yielding a response rate of approximately 80% based on the initially contacted participant pool of approximately 1313 educators. The responses included 450 from in-service teachers and 600 from pre-service teachers. The demographic breakdown revealed a gender distribution of 875 females and 175 males. In terms of age, the in-service teachers predominantly fell within the 30–45-year age bracket, while the pre-service teachers were mostly in their early twenties. Further demographic analysis indicated that 65% of the in-service respondents were married, and about 10% held a master's degree or higher. Additionally, 9% of the in-service teachers reported regular use of AR technologies in their teaching practices, highlighting a moderate adoption rate. On the other hand, 70% of the pre-service teachers expressed a strong interest in integrating AR technologies into their future teaching, suggesting a robust inclination towards embracing new educational technologies. Non-responses were handled through follow-up reminders sent two and four weeks after the initial survey distribution. This strategy aimed to maximize response rates and ensure a comprehensive data set for analysis. The collection of such detailed demographic data supports the thorough examination of trends and patterns regarding AR technology adoption among different teacher groups within the educational sector.

3.3. Measuring tools

The measurement tools utilized in this study were carefully developed through an extensive adaptation and validation process to ensure they met the necessary scientific standards and were appropriate for the local context. The scales were initially adapted from validated instruments cited in existing research, ensuring a strong foundation in established academic literature (Ajzen, 2019; Davis, 1989; Lu et al., 2009; Moon & Kim, 2001; Nikou & Economides, 2017; Taylor & Todd, 2005). Following the adaptation, the initial set of scale items was developed based on a comprehensive review of extant literature, targeting key constructs relevant to the study's theoretical framework. Pre-testing of the scale was conducted with a diverse group of 178 pre-service and in-service pre-school teachers to evaluate the clarity, relevance, and initial reliability of the items. This step was essential for refining the scales based on actual user feedback. Given the original scales were in English and the study was to be conducted in Turkish, a meticulous translation-back-translation method was employed, as recommended by Bracken and Barona (1991). This method ensured linguistic and conceptual consistency between the original and the translated versions, involving blind translations to eliminate biases. The translated scales underwent a thorough review by academicians proficient in both Turkish and English, who also had extensive knowledge of the relevant national and international literature. This review helped fine-tune the items to better fit the theoretical and cultural nuances of the study. Further validation was provided by three experts from the fields of pre-school education and computer and instructional technologies. Their expertise ensured the scales were appropriately adapted for the educational context being studied. The finalized scales were structured into four parts to comprehensively measure the constructs of the TAM, FT, and the TPB, along with the behavioral intention regarding technology use. The TAM-related items measured perceived ease of use and usefulness, the FT-related items assessed perceived enjoyment and concentration, and the TPB-related items evaluated attitude, subjective norm, and perceived behavioral control. Behavioral intention was also quantitatively assessed through four specific items. Each item was evaluated using a seven-point Likert scale, ranging from "Strongly disagree" (1) to "Strongly agree" (7), allowing for detailed gradations in participant responses. This approach not only ensured that the scales were robust and reliable but also sensitive to the subtleties of participant perceptions and attitudes. This meticulous development and validation process, documented in Table 2 of the study, ensured that the measurement tools were both scientifically robust and finely tuned to the specific context of the study, thereby enhancing the overall validity and reliability of the research findings.

3.4. Data analysis

The analytical phase of the study was systematically structured to rigorously test both the measurement and structural models, following the established guidelines by Anderson & Gerbing (1988). The

Table 2. Constructs, items, and results of reliability and validity.

Construct	Item	Statements	FL	α	AVE	CR
Attitude	ATT 1	I find using AR in preschool classes interesting.	0.83	0.81	0.63	0.87
	ATT 2	I believe that using AR in preschool classes positively impacts students' learning achievements.	0.76			
	ATT 3	Using AR is crucial for effective learning in preschool classes.	0.78			
	ATT 4	AR is beneficial for engaging preschool students' interests in classes.	0.81			
Subjective Norm	SN 1	Influential people in my professional circle recommend the use of AR in preschool classes.	0.74	0.75	0.57	0.73
	SN 2	My colleagues think that I should use AR in preschool classes.	0.77			
Perceived Behavioral Control	PBC 1	I feel in control when integrating AR into my preschool classroom.	0.80	0.82	0.65	0.85
	PBC 2	I am confident in my ability to use AR in preschool classes.	0.82			
	PBC 3	I can manage AR tools skillfully during preschool lessons.	0.79			
Perceived ease of use	PEOU 1	I find AR tools easy to operate during preschool lessons.	0.73	0.77	0.54	0.78
	PEOU 2	It is easy for me to become proficient at using AR tools in my teaching.	0.75			
	PEOU 3	My interaction with AR tools is intuitive and straightforward.	0.72			
Perceived usefulness	PU 1	Using AR enhances my teaching productivity in preschool classes.	0.70	0.78	0.55	0.78
	PU 2	AR tools are useful for enhancing educational outcomes in preschool lessons.	0.77			
	PU 3	Integrating AR in teaching helps me be more effective in preschool education.	0.75			
Perceived enjoyment	PE 1	I enjoy using AR tools during preschool lessons.	0.86	0.87	0.66	0.85
	PE 2	Using AR for teaching is fun and engaging.	0.79			
	PE 3	AR tools keep me excited and motivated during preschool classes.	0.78			
Concentration	CON 1	I am fully immersed and lose track of time when using AR tools in lessons.	0.84	0.86	0.67	0.86
	CON 2	I am completely focused and unaware of my surroundings when engaging with AR in preschool classes.	0.81			
	CON 3	My focus is solely on the lesson when I use AR tools, and I do not notice any distractions.	0.80			
Intention	INT 1	I intend to continue using AR in my future teaching practices.	0.85	0.88	0.69	0.87
	INT 2	I will consistently seek opportunities to use AR in my classes.	0.82			
	INT 3	I plan to regularly use AR as part of my teaching methodology in preschool education.	0.83			

Note. FL: Factor Loading, α = Cronbach's Alpha AVE: Average Variance Extracted, CR: Composite Reliability.

focus of the measurement model was to assess the reliability and validity of the constructs identified, while the analysis of the structural model was geared towards examining the fit of the theoretical model to the observed data and validating the research hypotheses, in line with methodologies suggested by Hair et al. (2018).

To ensure the robustness of the Structural Equation Modeling (SEM) approach, several key assumptions were carefully considered. These include the assumptions of normality, linearity, and homoscedasticity, which are essential for the validity of SEM results. Normality was assessed using skewness and kurtosis measures, while linearity and homoscedasticity were evaluated through residual plots. Additionally, the issue of multicollinearity was addressed by calculating Variance Inflation Factors (VIFs) for the independent variables, with all VIFs found to be well below the commonly accepted threshold of 10, indicating no significant multicollinearity.

Furthermore, alternative models were explored to ensure the robustness of the structural model. This included testing models with different combinations of paths and comparing their fit indices to the proposed model. The final model was selected based on its superior fit and theoretical justification, ensuring that the model not only fit the data well but also aligned with established theoretical frameworks.

3.4.1. Measurement model analysis

Confirmatory factor analysis (CFA) was utilized to scrutinize the measurement model using a maximum likelihood estimation method. The results from the CFA provided a robust indication of model fit: $\chi^2 = 502.36$, degrees of freedom (df) = 210, resulting in a χ^2/df ratio of 2.39, which is within the acceptable range, indicating a reasonable fit. The Goodness-of-Fit Index (GFI) was 0.92, the Incremental Fit Index (IFI) stood at 0.93, the Tucker-Lewis Index (TLI) was recorded at 0.92, and the Comparative Fit Index (CFI) reached 0.94. Additionally, the Root Mean Square Error of Approximation (RMSEA) was 0.05 and the Standardized Root Mean Square Residual (SRMR) was 0.04, both metrics suggesting a good fit to the underlying data structure, reflecting a model that accurately captures the intended constructs.

3.4.2. Reliability assessment

The reliability of the constructs was quantitatively assessed using Cronbach's alpha, a measure of internal consistency. The values ranged from 0.77 to 0.90 across different constructs. Each of these values surpassed the 0.70 benchmark, indicating satisfactory internal consistency and reliability according to the standards proposed by Fornell and Larcker (1981) and further supported by findings and recommendations from Hair et al. (2018).

3.4.3. Validity assessment

Construct validity was thoroughly evaluated through two primary dimensions: convergent validity and discriminant validity. For convergent validity, three parameters were considered crucial: Factor Loadings (FL), Average Variance Extracted (AVE), and Composite Reliability (CR). FL values ranged from 0.72 to 0.89, all exceeding the minimum recommended value of 0.50, suggesting strong loadings of items on their respective constructs. AVE values varied between 0.59 and 0.70, all surpassing the acceptable limit of 0.50, thereby indicating a satisfactory amount of variance captured by the constructs. CR values spanned from 0.81 to 0.90, well above the threshold value of 0.60, showcasing robust composite reliability of the constructs.

Discriminant validity was confirmed as the square roots of the AVEs for each construct were higher than the correlations with any other constructs, ensuring that each construct was distinctly different and adequately separated from others within the model. The values pertinent to the analysis are presented in Tables 2 and 3.

4. Findings

4.1. Goodness of fit statistics of the models and explanatory power

In the subsequent stage of our research, the structured model was critically assessed using Structural Equation Modeling (SEM) to evaluate the goodness of fit for three distinct theoretical frameworks: the TAM, Flow Theory, and the TPB. Additionally, a proposed integrated model that combines elements from all three frameworks was examined to determine if a

Table 3. Results of discriminant validity.

Constructs	ATT	SN	PBC	PEOU	PU	PE	CON	INT	$\sqrt{AVE}$
ATT	–								0.79
SN	0.42	–							0.76
PBC	0.39	0.37	–						0.81
PEOU	0.48	0.41	0.45	–					0.74
PU	0.50	0.43	0.47	0.64	–				0.74
PE	0.45	0.44	0.40	0.51	0.58	–			0.81
CON	0.33	0.31	0.34	0.35	0.37	0.55	–		0.82
INT	0.54	0.50	0.51	0.53	0.59	0.52	0.45	–	0.83

Table 4. Goodness of fit data and explanatory power of the models of TAM, TPB, flow theory, and combined proposed model.

Goodness fit statistics & R^2	TAM	TPB	Flow theory	Combined proposed model	Reference range
χ^2	338.91	320.45	365.88	613.20	N/A
df	135	138	140	280	N/A
χ^2/df	2.51	2.32	2.61	2.19	>1 and <5
CFI	0.92	0.95	0.91	0.97	≥0.90
GFI	0.92	0.94	0.91	0.95	≥0.90
IFI	0.93	0.95	0.92	0.96	≥0.90
TLI	0.93	0.95	0.92	0.95	≥0.90
SRMR	0.04	0.03	0.05	0.03	≤0.08
RMSEA	0.05	0.03	0.05	0.03	≤0.08
R2 (Adjusted) for Intention	0.49	0.52	0.44	0.54	N/A

synergistic approach could enhance our understanding of technology acceptance in educational settings.

The evaluation process involved rigorous statistical testing to ensure the models' adequacy in fitting the collected data. The fit was measured primarily through the chi-square to degrees of freedom ratio (χ^2/df), which provides a clear indication of the model's ability to replicate the observed data without overfitting (Bagozzi & Yi, 2012; Browne & Cudeck, 1993). Lower values in this metric generally indicate a better fit.

According to the results detailed in Table 4, the structured model demonstrated a commendable fit across all frameworks. However, it was the integrated model that emerged as particularly compelling. This model, which synergistically combines TAM, Flow Theory, and TPB, showed a chi-square to degrees of freedom ratio (χ^2/df) of 2.19, which was superior to the individual models: TAM (χ^2/df = 2.51), Flow Theory (χ^2/df = 2.61), and TPB (χ^2/df = 2.32).

Furthermore, the explanatory power of the models, quantified by the coefficient of determination (R^2), was also calculated. The R^2 values serve as an indicator of how much variance in the dependent variable can be explained by the independent variables included in the model. Here again, the proposed integrated model exhibited the highest explanatory power with an R^2 of 0.54, surpassing TAM ($R^2 = 0.49$), Flow Theory ($R^2 = 0.44$), and TPB ($R^2 = 0.52$).

These findings are significant as they suggest that the integration of TAM, Flow Theory, and TPB into a single model not only provides a better statistical fit but also offers greater explanatory power regarding the factors that influence technology acceptance among educators. The superior performance of the integrated model underscores the importance of considering multiple theoretical perspectives when studying technology adoption in educational settings.

4.2. Hypothesis testing

In the evaluation of our proposed model integrating the TAM, Flow Theory, and the TPB, we applied SEM to rigorously examine the interrelationships among the constructs. This comprehensive approach allowed us to assess how these constructs influenced one another and ultimately affected the intention to use AR technologies in preschool education settings.

The analysis revealed several significant paths. Perceived Ease of Use of AR technologies showed a strong positive influence on both Perceived Usefulness ($\beta = 0.47$, $p < 0.001$) and Attitude towards using these technologies ($\beta = 0.35$, $p < 0.001$). These results support Hypotheses H1 and H2, emphasizing the importance of user-friendly AR interfaces that are not only easy to operate but also perceived as beneficial by educators.

Furthermore, Perceived Usefulness was a crucial determinant of educators' attitudes ($\beta = 0.33$, $p < 0.001$) and their intentions ($\beta = 0.38$, $p < 0.001$) to adopt AR, confirming Hypotheses H3 and H4. These findings highlight that the perceived benefits of AR, such as enhanced learning outcomes, significantly impact educators' willingness to integrate these tools into their teaching.

Perceived Enjoyment also had a marked impact on attitudes ($\beta = 0.42$, $p < 0.001$) and intentions ($\beta = 0.25$, $p < 0.01$) to use AR, supporting Hypotheses H5 and H6. This underscores the role of emotional engagement in the adoption process, where enjoyable technology experiences are linked to positive attitudes and greater adoption intent.

The influence of Concentration, defined as the degree of focus and immersion experienced by users, significantly affected both attitudes ($\beta = 0.18$, $p < 0.01$) and intentions ($\beta = 0.21$, $p < 0.01$) towards AR use, affirming Hypotheses H7 and H8. This suggests that AR applications that can captivate and maintain educators' attention are more likely to be embraced and utilized.

The constructs from the Theory of Planned Behavior – Attitude ($\beta = 0.30$, $p < 0.001$), Subjective Norm ($\beta = 0.23$, $p < 0.01$), and Perceived Behavioral Control ($\beta = 0.27$, $p < 0.01$) – were each found to positively influence the intention to use AR, supporting Hypotheses H9, H10, and H11. These results highlight the importance of social influence, personal attitudes towards AR, and perceived control over the technology as significant predictors of technology adoption.

In summary, the model accounted for 26% of the variance in Perceived Usefulness, 51% in Attitude, and 54% in the Intention to use AR, indicating substantial explanatory power. These findings not only validate our model but also offer valuable insights for developers and educational practitioners aiming to enhance the effectiveness and appeal of AR technologies in preschool environments. Detailed results of these hypothesis tests are visually represented in Figure 2 and summarized in Table 5, demonstrating the robustness of our integrated model and its relevance to educational technology adoption research.

In examining the indirect effects within our study (see Table 6), results revealed that Perceived Ease of Use had a significant indirect impact on educators' Attitude towards adopting AR technologies, with a beta coefficient of 0.17 ($p < 0.05$). This indicates that the ease with which educators can use AR influences their positive attitude toward its integration into teaching practices. Additionally, several factors were found to contribute indirectly to the Intention to implement AR in classrooms. Specifically, the perceived usefulness of AR ($\beta = 0.16$, $p < 0.05$) subtly boosts intentions by

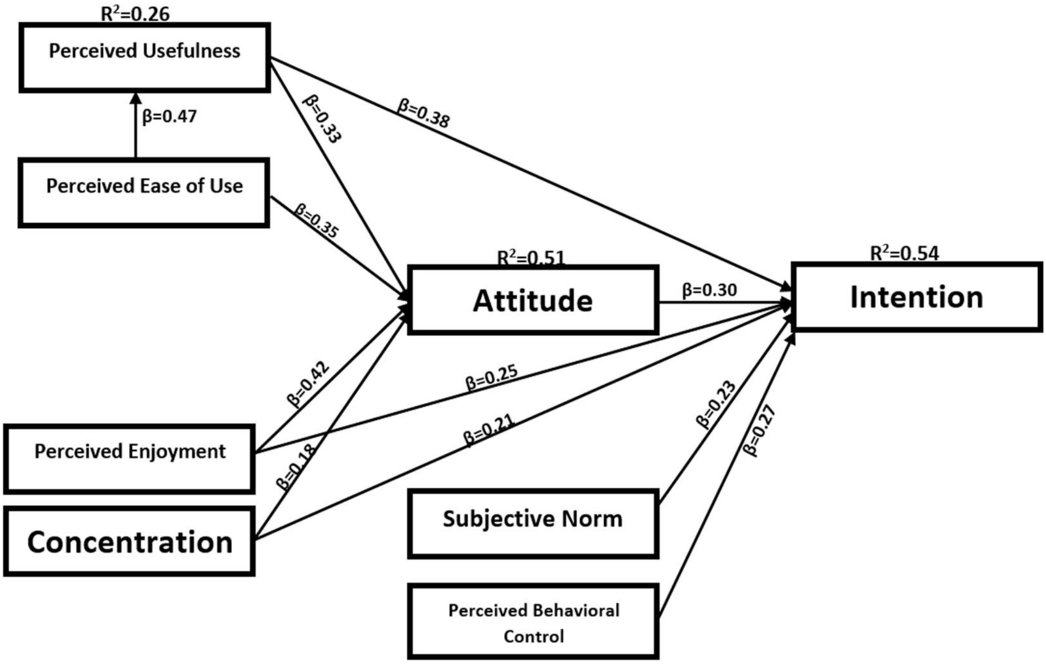

Figure 2. The SEM results.

Table 5. Structural equation modeling outcomes of the AR adoption framework.

Hypothesis	Pathway	Path Coefficient (β)	t-value	State
H1	PEOU → PU	0.47	10.89	Confirmed
H2	PEOU → ATT	0.35	7.98	Confirmed
H3	PU → ATT	0.33	7.08	Confirmed
H4	PU → INT	0.38	8.53	Confirmed
H5	PE → ATT	0.42	9.84	Confirmed
H6	PE → INT	0.25	4.12	Confirmed
H7	CO → ATT	0.18	2.73	Confirmed
H8	CO → INT	0.21	3.12	Confirmed
H9	ATT → INT	0.30	5.78	Confirmed
H10	SN → INT	0.23	3.84	Confirmed
H11	PBC → INT	0.27	4.89	Confirmed

Table 6. Indirect effects of AR adoption factors in preschool education.

Factor	Target variable	Beta coefficient	*p*-value	Description
PEOU	ATT	0.17	<0.05	Indicates how the usability of AR technologies positively influences educators' attitudes.
PU	INT	0.16	<0.05	Shows that the practical benefits of AR subtly enhance intentions to use it in teaching.
CO	INT	0.13	<0.05	Suggests that deeper engagement with AR supports adoption intentions.
PE	INT	0.18	<0.05	Highlights the role of positive emotional responses to AR in fostering a willingness to use it.

underscoring the practical benefits AR offers. The immersive nature of AR, measured as Concentration, also indirectly supports adoption intentions ($\beta = 0.13$, $p < 0.05$), suggesting that the depth of engagement with AR can enhance the likelihood of its use. Furthermore, the enjoyment educators derive from using AR technologies (Perceived Enjoyment) also plays a critical role, with a beta value of 0.18 ($p < 0.05$), highlighting that positive emotional responses to AR are crucial for fostering a willingness to use these tools in educational settings. These findings highlight the complexity of factors that influence AR adoption and emphasize the importance of addressing multiple dimensions of user experience to facilitate effective technology integration in education.

4.3. Examining the moderating effects of participant type

In our investigation of AR use in preschool education, we conducted an invariance test for both the measurement and structural models to examine the moderating effect of participant type, following the approach suggested by Kline (2015). The study incorporated two distinct groups: 450 pre-service teachers and 600 in-service teachers, allowing us to explore differences in how these groups perceive and use AR technologies.

The analysis began by assessing the fit of the non-restricted model and the full-metric invariance model across both groups. The non-restricted model, which allows parameters to vary between groups, showed a good fit to the data ($\chi^2 = 1186.24$, df = 635; χ^2/df = 1.87, CFI = 0.96, IFI = 0.97, TLI = 0.96, RMSEA = 0.047), as did the full-metric invariance model ($\chi^2 = 1237.45$, df = 659; χ^2/df = 1.88, CFI = 0.95, IFI = 0.96, TLI = 0.95, RMSEA = 0.048). These results suggested that the model parameters fit well within each group independently.

Subsequently, we conducted a chi-square difference test to determine whether there were statistically significant differences between the non-restricted and full-metric invariance models. The results indicated no significant difference ($\Delta\chi^2(24) = 51.21$, $p > 0.05$), supporting the assumption of full-metric invariance and suggesting that the relationships modeled were consistent across the two groups of teachers.

To delve deeper, we developed a baseline model by integrating proposed relationships into the full-metric invariance framework. This baseline model was then compared to a nested model, which allowed us to examine specific paths for differences across the groups. The baseline model exhibited an excellent fit with the data ($\chi^2 = 1453.98$, df = 721; χ^2/df = 2.02, CFI = 0.92, IFI = 0.92, TLI = 0.91, RMSEA = 0.053), indicating robustness in the structural integrity of the proposed relationships.

Significant differences were observed in the relationships from Perceived Enjoyment (PE) and Concentration (CON) to Intention (INT) to use AR, with differences more pronounced between pre-service and in-service teachers. Specifically, the paths from PEOU to INT ($\Delta\chi^2(1) = 6.28$, $p < 0.05$) and from PE to INT ($\Delta\chi^2(1) = 7.14$, $p < 0.05$) differed significantly, suggesting that pre-service teachers might be more influenced by enjoyment and immersion than in-service teachers when deciding to use AR technologies.

These findings underscore the importance of considering the unique characteristics and experiences of different educator groups in the adoption and integration of AR in preschool environments.

Table 7. Invariance test results for participant type related to the measurement and structural models.

Groups	Models	χ^2	df	RMSEA	CFI	IFI	TLI	$\Delta\chi^2$	Full-metric invariance
Pre-service and in-service teachers	Non-restricted model	1186.24	635	0.047	0.96	0.97	0.96	$\Delta\chi^2(24) = 51.21$, $p >$ 0.05 (insignificant)	supported
	Full-metric invariance	1237.45	659	0.048	0.95	0.96	0.95		
Paths	Pre-service teachers (n = 450)	In-service teachers (n = 600)			Baseline model (Freely estimated)			Nested model (Constrained to be equal)	
	Β and t-values	β and t-values							
PEOU → PU	$\beta = 0.34$, $t = 7.19$	$\beta = 0.59$, $t =$ 13.48			$\chi^2(721) = 1453.98$			χ^2 (722) = 1460.26[a]	
PEOU → ATT	$\beta = 0.31$, $t = 6.51$	$\beta = 0.38$, $t =$ 7.78			$\chi^2(721) = 1453.98$			χ^2 (722) = 1456.02[b]	
PU → ATT	$\beta = 0.30$, $t = 6.02$	$\beta = 0.35$, $t =$ 6.81			$\chi^2(721) = 1453.98$			χ^2 (722) = 1455.61[c]	
PU → INT	$\beta = 0.36$, $t = 7.98$	$\beta = 0.39$, $t =$ 8.23			$\chi^2(721) = 1453.98$			χ^2 (722) = 1455.65[d]	
PE → ATT	$\beta = 0.41$, $t = 9.34$	$\beta = 0.45$, $t =$ 9.41			$\chi^2(721) = 1453.98$			χ^2 (722) = 1456.11[e]	
PE → INT	$\beta = 0.19$, $t = 2.62$	$\beta = 0.33$, $t =$ 5.88			$\chi^2(721) = 1453.98$			χ^2 (722) = 1461.12[f]	
CO → ATT	$\beta = 0.16$, $t = 1.93$	$\beta = 0.20$, $t =$ 2.23			$\chi^2(721) = 1453.98$			χ^2 (722) = 1456.44[g]	
CO → INT	$\beta = 0.22$, $t = 3.19$	$\beta = 0.20$, $t =$ 2.49			$\chi^2(721) = 1453.98$			χ^2 (722) = 1455.11[h]	
ATT → INT	$\beta = 0.31$, $t = 6.78$	$\beta = 0.31$, $t =$ 5.02			$\chi^2(721) = 1453.98$			χ^2 (722) = 1455.44[i]	
SN → INT	$\beta = 0.22$, $t = 3.04$	$\beta = 0.24$, $t =$ 3.01			$\chi^2(721) = 1453.98$			χ^2 (722) = 1455.59[j]	
PBC → INT	$\beta = 0.24$, $t = 4.19$	$\beta = 0.29$, $t =$ 4.47			$\chi^2(721) = 1453.98$			χ^2 (722) = 1455.49[k]	

a $\Delta\chi^2$ (1) = 6.28, $p < 0.05$ (significant)
b $\Delta\chi^2$ (1) = 2.04, $p > 0.05$ (insignificant)
c $\Delta\chi^2$ (1) = 1.63, $p < 0.05$ (insignificant)
d $\Delta\chi^2$ (1) = 1.67, $p > 0.05$ (insignificant)
e $\Delta\chi^2$ (1) = 2.13, $p > 0.05$ (insignificant)
f $\Delta\chi^2$ (1) = 7.14, $p < 0.05$ (significant)
g $\Delta\chi^2$ (1) = 2.46, $p > 0.05$ (insignificant)
h $\Delta\chi^2$ (1) = 1.13, $p > 0.05$ (insignificant)
i $\Delta\chi^2$ (1) = 1.46, $p > 0.05$ (insignificant)
j $\Delta\chi^2$ (1) = 1.61, $p > 0.05$ (insignificant)
k $\Delta\chi^2$ (1) = 1.61, $p > 0.05$ (insignificant)

The results of the structural invariance tests are detailed in Table 7, providing a comprehensive view of how participant type moderates the relationships within the proposed model.

5. Discussion

This study combined the TAM, Flow Theory, and the TPB to create a comprehensive framework for understanding both in-service and pre-service preschool teachers' intentions to adopt AR. The study validated the theoretical associations, confirming the significant roles of perceived usefulness, perceived ease of use, and attitude as mediators. Additionally, it explored how the sample type (pre-service versus in-service teachers) moderated these relationships within the proposed model. These findings contribute significantly to the educational technology literature by emphasizing the individual, social, and motivational factors that influence AR adoption among teachers. Furthermore, the results can inform the development of effective AR integration strategies, supporting educators in enhancing their skills in using AR-based tools in preschool settings.

However, beyond these individual and motivational factors, the broader environmental context in which educators operate also plays a crucial role in the adoption of AR technologies. Technological infrastructure, for instance, is a significant barrier to AR adoption (Alzahrani, 2020). Schools and preschools without robust technological infrastructure, including unreliable internet access, outdated hardware, and insufficient technical support, are less likely to successfully integrate AR into their curricula (Alalwan et al., 2020). Economic constraints are another critical factor (Dalili Saleh et al., 2022). The cost of AR technology, including devices, software, and maintenance, can be prohibitive for many educational institutions, particularly in regions with limited funding for educational innovations. These economic challenges necessitate strategic investments and potentially the development of more affordable AR solutions tailored to the needs of lower-income schools. Policy environments also significantly influence AR adoption (Alalwan et al., 2020). Supportive educational policies that encourage the integration of digital technologies, provide funding for technological upgrades, and offer professional development opportunities for educators can greatly facilitate the adoption of AR. On the other hand, restrictive or outdated policies that do not prioritize technological advancement can act as barriers, preventing schools from fully embracing these innovations. Understanding these policy contexts is essential for developing strategies that align with national or regional educational goals and regulations. By considering these broader environmental factors, this study not only enhances our understanding of AR adoption from an individual and motivational perspective but also provides a more holistic view that includes the systemic enablers and barriers to technology integration in education.

5.1. Theoretical implications

The primary theoretical implication of this research is the development of a composite model that integrates the TAM, Flow Theory, and the TPB to elucidate the behavioral intentions of preschool teachers toward adopting AR technologies. This model innovatively combines elements of technological ease of use and usefulness (TAM), engagement and enjoyment (Flow Theory), along with social and personal control factors (TPB), within the context of early childhood education. The findings indicate that both intrinsic motivations, such as enjoyment derived from the use of AR, and extrinsic motivations, like the perceived ease of use, significantly influence teachers' intentions to adopt AR technologies. Moreover, while internal factors such as personal attitudes and the perceived usefulness of AR are potent mediators forming the behavioral intention to use AR, not all external influences like subjective norms or perceived behavioral controls showed a strong impact on these intentions. This nuanced discovery underscores the complex interplay of personal, social, and functional factors in the adoption of educational technologies, offering deep insights into the multifaceted process of integrating innovative technologies into educational settings. Additionally, this integration of multiple models not only enhances our understanding of AR adoption but also provides a framework that can potentially be applied to other forms of educational technology. This suggests that the composite model developed in this study could be extended to examine the adoption of different digital tools in various educational contexts, thereby broadening its applicability beyond AR.

Secondly, this research substantiates the distinct motivational constructs of the TAM, Flow Theory, and the TPB in the context of augmented reality adoption in preschool education. This exploration acknowledges the theoretical framework established by Davis (1989) and others, which posits that distinct motivational influences – such as perceived ease of use and perceived usefulness (TAM) – directly impact the adoption of new technologies. This study enriches this framework by integrating intrinsic motivators from Flow Theory, such as engagement and enjoyment, and the broader social and behavioral controls from TPB. The findings reveal that educators' motivations to adopt AR are not merely based on utilitarian values but also deeply rooted in the experiential enjoyment they derive from using such technologies. Educators who find AR engaging are likely to advocate for its incorporation into their teaching regimes, driven by positive experiences that go beyond traditional motivations of convenience and functionality. Conversely, educators facing significant hurdles in technology integration, such as lack of support or technical challenges, are less inclined to adopt AR unless these external constraints are adequately addressed within their institutional or personal norms (Perifanou et al., 2023). Thus, this research significantly advances the discourse on technology adoption in education by delineating how various motivational dimensions, both intrinsic and extrinsic, shape educators' intentions to use AR. Furthermore, the integration of these models provides a robust foundation for exploring how similar motivational factors might influence the adoption of other technologies in educational settings, particularly those that also require a balance of ease of use, engagement, and social acceptance.

Third, this study has demonstrated that preschool educators are predominantly driven by intrinsic motivations when deciding to adopt AR technologies. The activation of intrinsic values, such as personal interest in innovative teaching methods and the enjoyment derived from using AR, was found to be a more significant determinant than extrinsic motivational factors like perceived behavioral control or subjective norms. Educators can thus be categorized as a group whose adoption choices are significantly influenced by personal interest and internal satisfaction with AR technology. This observation aligns with prior research that identifies intrinsic motivation as a critical factor in the adoption of educational technologies (e.g. Ateş & Yilmaz, 2024; Luarn et al., 2023; Shahzad et al., 2020). Interestingly, this study also found that awareness of the benefits of AR did not consistently enhance adoption intention. While conventional wisdom and previous studies suggest that increasing awareness about technology's benefits generally promotes adoption (e.g. Al-Emran & Griffy-Brown, 2023; Ali et al., 2023), the findings here indicate that merely being aware of AR's educational benefits does not necessarily translate into a higher motivation to adopt such technologies. This may be due to the unique challenges and demands that AR integration poses in preschool environments, suggesting that mere awareness is insufficient without addressing the practical challenges and personal readiness of educators (Ateş & Garzón, 2023). These insights imply that the emphasis on intrinsic motivation and the effective addressing of practical challenges should be considered when promoting the adoption of any new educational technology, not just AR.

5.2. Practical implications

This research has several practical implications for integrating AR in preschool education settings, with specific strategies for various stakeholders in the education sector, including educators, policymakers, and curriculum designers.

The study suggests that segmentation of educators based on their motivations for adopting AR can guide the development of targeted strategies for technology implementation. Preschool educators can be classified into two groups: technophiles and pragmatists. Technophiles, driven by intrinsic interest in new technologies and their potential to enhance teaching, should be provided with advanced workshops and continuous learning opportunities about the latest AR applications. These opportunities will help maintain their interest and promote deeper engagement with the technology. Conversely, pragmatists, who are more concerned with the feasibility of integrating AR into their routines, would benefit from straightforward training sessions that focus on practical implementation, along with robust technical support. These strategies should emphasize the simplicity of AR technology integration, the availability of support and resources, and the tangible benefits for both teachers and students.

The study highlights the importance of developing differentiated support systems to cater to the distinct needs of technophiles and pragmatists. Policymakers should consider implementing pilot programs that allow educators to experience and evaluate AR technologies in a controlled environment. These programs should be designed to collect feedback from both groups, ensuring that the AR tools meet the diverse needs of all educators. Additionally, policymakers should focus on creating a supportive regulatory environment that encourages innovation while ensuring that the integration of AR aligns with educational standards and goals.

The activation of personal and social norms was identified as a key psychological mechanism influencing educators' adoption of AR technologies. Curriculum designers should, therefore, focus on enhancing the social and ethical appeal of using AR in teaching. This involves promoting AR as a tool that enriches the teaching experience while adhering to pedagogical ethics by supporting diverse learning needs and styles. Curriculum designers should work closely with educators to develop AR applications that are customizable and adaptable to various subjects and learning environments. This collaboration ensures that AR content is relevant and aligned with educational objectives, making it easier for educators to integrate these technologies into their teaching practices.

Furthermore, educational institutions should foster a culture that values ethical technology use in education. For educational leaders and administrators, strategies that increase teachers' sense of responsibility towards implementing AR can be more effective than those merely aiming to raise awareness of the challenges. This approach involves portraying potential technical or integration challenges as manageable and within the teacher's capability to overcome. By fostering a sense of competency and ownership, institutions can encourage more active and enthusiastic adoption of AR, minimizing negative perceptions that may deter educators from embracing such technologies.

Distinctive strategies should be developed for educators who frequently use AR, as they display a more positive attitude towards its integration into the curriculum. Traditional methods of promoting technology adoption may not be effective for this group. Instead, there should be a focus on developing innovative AR applications that align with their teaching goals and interests. The use of big data analytics to tailor AR content and features to the specific needs and preferences of highly engaged educators can make AR more appealing and practically useful. Marketing strategies aimed at this segment should highlight the unique benefits of enhanced AR tools, such as increased student engagement and improved learning outcomes, which directly align with the intrinsic motivations of educators who value progressive educational tools.

In essence, by acknowledging the different motivational drivers of preschool educators and providing tailored support and resources, educational institutions, policymakers, curriculum designers, and technology developers can more effectively foster a positive environment for the adoption of AR technologies. This comprehensive approach not only enhances learning outcomes but also embraces the full potential of digital innovation in early childhood education.

5.3. Limitations and suggestions for future studies

This study, while providing valuable insights into the adoption of AR technologies in preschool settings, has several limitations that warrant consideration. First, the generalizability of the findings is potentially limited due to the regional focus of the study, which predominantly sampled educators from specific areas in Turkey. To enhance the applicability of the findings, future research should explore similar models in different cultural or educational contexts, thereby validating and extending the results across diverse populations. Conducting studies in various geographic locations can help determine whether the observed patterns hold true in different settings, thereby improving the external validity of the research.

Second, the study primarily utilized self-reported data, which can introduce biases related to personal perceptions and social desirability. In future research, incorporating longitudinal studies would be beneficial to observe changes in attitudes and adoption over time, providing a dynamic perspective on the integration of AR in education. Additionally, using more objective measures of AR usage, such as observational data or log analytics from AR applications, could offer a more nuanced understanding of how AR is being integrated into teaching practices and its long-term impact.

Third, this research did not account for the varying levels of technological infrastructure available in different preschool environments, which can significantly influence the feasibility and effectiveness of AR implementation. Future studies should examine the impact of infrastructural variations on AR adoption and explore strategies to mitigate technology-related barriers in under-resourced settings. This approach would help identify specific challenges and opportunities in different educational contexts, ensuring that AR technologies can be effectively implemented regardless of resource availability.

Finally, the rapid evolution of AR technology itself suggests a need for ongoing research to keep pace with technological advancements. Future studies should consider investigating the implications of emerging AR features, such as increased interactivity and improved user interfaces, on their adoption and educational outcomes. As AR technologies continue to develop, it will be important to understand how these advancements affect both educators' willingness to adopt the technology and the effectiveness of AR in enhancing educational practices.

6. Conclusion

This research significantly advances our comprehension of the elements driving preschool educators' adoption of AR technologies. By synthesizing the TAM, Flow Theory, and the TPB, this study has constructed a comprehensive theoretical framework that adeptly elucidates the multifaceted decision-making processes educators undergo when considering new technological tools. The results emphasize the critical impact of perceived ease of use, perceived usefulness, and the motivational enjoyment derived from AR, all of which are pivotal in shaping educators' intentions to implement AR in their classrooms. The findings reveal that educators' psychological readiness and their recognition of AR's educational benefits are key predictors of their willingness to adopt this technology. Moreover, the influence of subjective norms within the educational community significantly bolsters this propensity. This underscores that while individual attitudes and perceptions are essential, the broader social and institutional context also plays a significant role in influencing technology adoption decisions. From a practical standpoint, these insights offer valuable guidance to educational administrators and policy makers. They highlight the importance of developing targeted training programs that enhance educators' technological proficiency, supplying the necessary resources, and fostering a supportive community that encourages the exploration and adoption of AR. Additionally, this study suggests further research avenues, particularly the exploration of AR adoption across varied educational environments and age groups to validate the generalizability and applicability of the established model. In essence, this research enriches our understanding of the dynamic interaction between individual, motivational, and contextual factors in the adoption of educational technology. It lays a solid foundation for formulating effective strategies to incorporate advanced technologies like AR into educational frameworks, aiming to amplify teaching quality and enrich student learning outcomes. As we navigate the evolving educational terrain shaped by rapid technological advances, this study serves as a crucial resource for navigating the challenges and leveraging the opportunities that these innovations bring to educational practices.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Notes on contributors

Ayşegül Şakır is an Associate Professor at Kırşehir Ahi Evran University, where she serves in the Department of Elementary Education, specializing in Preschool Education within the Faculty of Education. Her academic focus is rooted in the Social-Humanities and Administrative Sciences, specifically in Child Development and Preschool Education. Ayşegül holds a distinguished position with an ORCID identifier of 0000-0002-2979-7899 and an unique researcher ID of 46939. Ayşegül began her academic journey at Hacettepe University, where she earned her undergraduate degree in Child Development and Education from the School of Home Economics from 1979 to 1984. She continued her education at Gazi University, where she received her Master's degree in Child Development and Education from the Institute of Social Sciences in 1987. Her thesis investigated the relationship between social adaptation and parental attitudes among 14–18 year-olds attending Hacettepe University State Conservatory. Ayşegül then returned to Hacettepe University for her doctoral studies, receiving her PhD in 1990 from the Institute of Health Sciences, where she focused on the heterosexual development of students aged 14–18 at the Hacettepe University State Conservatory. Since joining Ahi Evran University in 2021, Ayşegül has been an active contributor to the faculty, teaching and mentoring within the realm of early childhood education. Her scholarly work and collaborations continue to influence the field, enriching the educational experiences of her students and shaping future educational practices.

ORCID

Ayşegül Şakir http://orcid.org/0000-0002-2979-7899

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