Factors affecting pre-service teachers to adopt augmented reality in science learning

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ABSTRACT

The advancement of augmented reality (AR) technology and its application in education presents an opportunity for pre-service teachers to incorporate it into the learning process, particularly in science subjects with abstract and microscopic materials. However, the adoption of AR technology among pre-service teachers remains suboptimal. Therefore, this study aims to analyze the factors influencing pre-service teachers' adoption of AR in science learning. By employing partial least squares structural equation modeling, we gathered 211 responses through a questionnaire. The developed model has met the criteria of validity and reliability. The study's findings reveal that perceived control and learning content significantly influence behavioral intention, while visual attraction and knowledge-ability do not. Clearly, their focus is on pedagogically implementing AR technology rather than visually developing it. Thus, it is recommended to provide training for pre-service teachers to apply AR science because many of them need an understanding of integrating this technology as a science learning media. This research implies offering insightful analysis and practical suggestions for the successful integration of AR technology into science learning, especially by addressing the variables affecting its uptake.

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1. INTRODUCTION

Augmented reality (AR) represents a rapidly growing impact of technological advancements worldwide [1]. Its far-reaching influence extends to various fields, particularly in education [2]. Due primarily to many students encountering challenges in learning, especially in subjects demanding strong visualization skills like science, AR technology can serve as a viable solution to enhance their understanding [3]. By harnessing the ability to overlay virtual information onto the real world, AR technology can potentially immerse students in authentic learning environments. Science education can become genuinely engaging and meaningful when grounded in experiences relevant to the students.

One effective approach is through simulations and visualizations, providing a foundation for experiential learning by modelling complex real-world systems. This enables students to experiment with systems, manipulate parameters, or participate in them while observing outcomes [4]. AR applications can create an illusion of users experiencing real events or phenomena, stimulating motivation and engagement [5]. The versatility of AR allows students to view and manipulate learning materials from various angles, enhancing their understanding.

The integration of AR into education not only aids students but also assists teachers in fostering interaction. AR offers a novel educational experience, making learning more effective and interactive, especially in the post-COVID-19 pandemic [6]. It is user-friendly and cost-effective, aligning with the adjustment to new learning habits. In the field of science education, strategies combining AR technology with laptops and textbooks have evolved [7], [8]. Empirical evidence presented that utilizing AR can significantly enhance motivation [9] and learning outcomes [10] in a science course.

In spite of the rapid development of AR technology and its growing benefit alongside acceptance among students, there remain some discrepancies. Teachers, for instance, do not consistently incorporate AR into science lessons, hindering its potential impact [11]. Hence, the level of adopting AR in education remains unsatisfactory [12]. On the other hand, integrating AR into science learning not only benefits students but also helps pre-service science teachers (PSTs) develop their technology skills, creative teaching methods, and adaptability in the classroom, making them better-equipped educators for the future [13]. Various factors influence PSTs' acceptance and behavioral intention (BI) to use AR. As a result, it is imperative to identify the determinants affecting AR adoption among PSTs. This research contributes valuable insights and recommendations for the effective implementation of AR technology in science education, particularly by addressing the factors influencing its adoption. This study's objective is to identify the factors affecting PSTs to adopt AR in science learning.

2. LITERATURE REVIEW

2.1. Visual attraction

Visual attraction (VA) refers to the degree to which the visual aspects of AR applications, such as graphics, animations, and overall visual appeal, captivate and engage users [14]. Visual attraction plays a significant role in AR adoption because it influences how users perceive and interact with AR content [15]. There is evidence to suggest that the visual attractiveness of AR can affect its adoption. For instance, implementing AR technology in mobile shopping can make the digital shopping experience more efficient by providing visual and tactile information about products, which can increase consumer responses [16]. Additionally, scholars have found that AR can improve students' attraction to learning mechanisms by increasing content understanding and long-term memory retention [17]. Thus, the hypothesis was proposed: Visual attraction positively influences behavioral intention (H1).

2.2. Knowledge-ability

Knowledge-ability (KA) typically indicates an individual's or user's capacity or competence to effectively acquire, understand, and apply knowledge and information presented through AR technology [18], [19]. This concept encompasses various aspects of a PSTs' ability to interact with AR systems and the knowledge required to make meaningful use of the technology [20], possibly affecting teachers' adoption of AR. Proficiency in AR technology enhances their teaching efficacy by employing innovative tools and methods that engage students effectively, making science learning more captivating [21]. Empirical evidence also showed that knowledge-ability affects students' continuance intention in basic design courses [15]. Thus, the hypothesis was proposed: Knowledge-ability positively influences behavioral intention (H2).

2.3. Perceived control

Research by Ajzen [22] described the concept of perceived behavioral control in his theory of planned behavior as a predictor of behavioral intention. According to Ly *et al*. [23], perceived control (PC) is a reflection of how in control a user feels about the task at hand and the surroundings. Whereas mobile AR apps are a new service that could present difficulties for PSTs, they could feel out of control if the obstacles exceed their abilities [24]. This could weaken their experience. They might be concerned about the danger and unpredictability of utilizing augmented reality apps. On the other hand, PSTs might become more confident in their capacity to use AR in science learning if they feel in control [12]. This could enhance their experience and encourage usage. Thus, the hypothesis was proposed: Perceived control positively influences behavioral intention (H3).

2.4. Learning content

Science learning content is essential because it differs from other subjects. Science often involves abstract concepts that can be challenging to convey using traditional teaching methods, compared to other subjects [25]. AR allows both PSTs and students to visualize and simulate complex scientific phenomena, such as electromagnetism, modern physics, atomic theory, chemical sciences, and molecular biology [26]. In addition, science learning tends to be less attractive to students due to the fact that they may have negative experiences in science classes that lead to a lack of interest. For example, students may describe the material as irrelevant to their lives and future, and as a result, they seem to take an apathetic approach to their learning

[27]. The engineering learning content is one factor that influences the adoption of particular simulation technologies by PSTs [28]. Therefore, this factor also influences the adoption of AR in science learning. Thus, the hypothesis was proposed: Learning content (LC) positively influences behavioral intention (H4).

3. METHOD

Based on the research objectives, this research uses a quantitative type with data analysis tailored to the research pattern and the variables studied. The model used in this study is a causality model to test whether the latent variables VA, KA, PC, and LC affect BI using partial least square-structural equation modelling (PLS-SEM) operated through the SmartPLS 3 program [29]. This research procedure begins with determining the hypotheses as factors that influence PSTs to adopt AR in science learning. Afterwards, a questionnaire was developed based on latent variables elaborated through relevant indicators using a Likert scale of 1-5. Table 1 shows the latent variables along with their indicators on the questionnaire. The total number of favorable items is 9, while the unfavorable one is 8. This is because respondents may generally agree with all statements, which can lead to acquiescent bias. Alternating between positive and negative items can reduce this bias [30].

Table 1. Latent variables and their indicators

Latent variable	Indicator
Visual attraction	I feel interested in the visualizations presented through AR technology.
	I believe that using AR cannot increase my interest in learning science. (-)
	I find the visual features of AR to be interesting and have the potential to improve understanding of science concepts.
	I am not interested in seeing how AR can enrich the visual learning experience. (-)
Knowledge-ability	I feel confident that I can use AR effectively in science learning.
	I believe that using AR can help me understand science concepts better.
	I feel unable to overcome the challenges that may arise in using AR in science learning. (-)
Perceived control	I believe that I cannot control and manage the use of AR in science learning. (-)
	I feel confident that I cannot use AR well in science learning according to my needs. (-)
	I believe that I can organize relevant AR features in science learning.
Learning content	I feel that science learning materials are more difficult to understand when using AR aids. (-)
	The integration of AR in science learning can increase the attractiveness and effectiveness of learning materials.
	The use of AR cannot help me in connecting science concepts with real-world situations. (-)
	I believe that the use of AR can enrich science learning content.
Behavioral intention	I will likely use AR in science learning if the opportunity arises.
	Along with technology development, I do not plan to apply AR in science learning. (-)
	I intend to use AR in science learning in the future.

Note: Items with a (-) sign indicate unfavorable ones

Subsequently, the questionnaire was validated by two experts in science education. Based on their assessment results, the content validity score is 3.5 (Very valid), while the construct validity score is 3.83 (Very valid), with an 85.71% percentage of agreement score. Once the questionnaire meets the valid criteria, the next step is a limited sample test outside the specified sample criteria to determine the reliability of the questionnaire. In this test, the Cronbach alpha value of 0.885 is obtained, exceeding the threshold of 0.7 [31], thus meeting the valid criteria, and questionnaires can be used in data collection.

In the data collection process, sample criteria were established from the study population using a cluster random sampling technique, which focused on pre-service science teachers who have taken or are currently taking science learning media courses or similar. By utilizing the G*Power software [32], the minimum sample requirement for 0.15 effect size, 5% error probability, and 4 predictors was 129 participants. In fact, 215 responses were collected, and 211 were determined to be valid (98.14%), fulfilling the sampling criteria. This response is used in further data analysis, where the description of respondents is presented in Table 2. Validity and reliability are the two primary criteria utilized in PLS-SEM analysis to evaluate the outer model, or measurement model [33]. A five-step structural model assessment approach was suggested by Hair *et al.* [34] to evaluate the model: i) the structural model for the collinearity issue; ii) the path coefficient, *t*-value, and p-value; iii) the level of R^2; iv) the effect size f^2; and v) the predictive relevance.

Table 2. Respondents' profile

Characteristics		Frequency	Percentage (%)
Study program	Science education	46	21.80
	Physics education	86	40.76
	Chemistry education	53	25.12
	Biology education	26	12.32
Entry year	2021	86	41.23
	2020	55	26.07
	2019	69	32.70
Age	19-20	85	40.76
	21-22	112	53.08
	23-24	13	6.16
Gender	Male	29	13.74
	Female	182	86.26

4. RESULTS

4.1. Evaluation of outer model

Ensuring the instrument is reliable, and the variables consistently measure the construct is the first stage in the outer model assessment of PLS-SEM analysis as presented in Table 3. Both Cronbach's alpha and construct reliability (CR) are used to assess the model's internal consistency. Whereas a score between 0.6 and 0.8 indicates good construct reliability, Cronbach's alpha values exceeding 0.7 indicate good reliability [35]. Convergent and discriminant validity tests are the two kinds of validity assessments that are carried out. The degree to which one measure of a construct positively correlates with another is known as convergent validity. The average variance extracted (AVE) and item loadings are assessed in order to assess convergent validity in PLS-SEM [29]. When the construct's AVE value is higher than 0.50, it means that the construct typically accounts for more than half of the indicator variance. Therefore, it is generally accepted that an AVE value equal to or greater than 0.50 is considered satisfactory [29].

As shown in Table 4, discriminant validity measures how items can distinguish between constructs or assess distinct concepts. This is achieved by calculating and examining the relationships between measures of potentially overlapping variables [36]. Discriminant validity is assessed by studying the correlations between the measures of potentially overlapping constructs. For discriminant validity to be established, the AVE for each component should exceed the squares of the correlations between that component and all other components. Conversely, when the component correlations are smaller than the AVE square root, the research model is said to have strong discriminant validity [29].

Table 3. Variables, indicators, SLF, CR, AVE, and Cronbach's alpha

Variable	Indicator	Loading	CR	AVE	Cronbach's alpha
VA	VA1	0.738	0.833	0.556	0.736
	VA2	0.779			
	VA3	0.712			
	VA4	0.750			
KA	KA1	0.838	0.837	0.632	0.742
	KA2	0.731			
	KA3	0.812			
PC	PC1	0.742	0.854	0.661	0.741
	PC2	0.855			
	PC3	0.838			
LC	LC1	0.860	0.863	0.615	0.785
	LC2	0.738			
	LC3	0.880			
	LC4	0.634			
BI	BI1	0.828	0.866	0.684	0.772
	BI2	0.907			
	BI3	0.739			

4.2. Evaluation of inner model

Adequate discriminant and convergent validity were shown by the measurement model. Consequently, the next stage of PLS-SEM analysis is to examine the inner model in order to create a structural model that can be utilized to evaluate the connections between the constructs. Path coefficients, R^2, f^2, predictive relevance, and collinearity issues are all included in the evaluation of the inner model. The development of this structural model is crucial for understanding the dynamics of relationships between variables within the established conceptual framework.

In terms of collinearity, this issue occurs when the variance inflation factor (VIF) value exceeds 5.00 [29]. The data obtained in this study indicates that the inner VIF falls within the range of 1.219 to 2.334, indicating the absence of such problems. The evaluation of path coefficients is conducted through the t-statistic value, which is estimated using the bootstrap resampling procedure. This resampling procedure is a non-parametric method used to assess the accuracy of results derived from PLS-SEM [29]. The bootstrapping results demonstrate the stability of the PLS-SEM estimation outcomes. Based on the findings presented in Table 5, it can be concluded that a hypothesis is accepted when the *p*-value falls within the range of 0.000 to 0.011, and is less than 0.05 for each variable relationship. Similarly, Figure 1 depicts measurement and model estimation among latent variables, summarizing the estimated empirical model.

Table 4. Discriminant validity

	BI	KA	LC	PC	VA
BI	0.827				
KA	0.227	0.795			
LC	0.508	0.415	0.784		
PC	0.388	0.343	0.511	0.813	
VA	0.340	0.540	0.607	0.457	0.745

Table 5. Path coefficients and results of hypotheses testing

Hypothesis	Relationship	*t*-value	*p*-value	Decision
H1	VA → BI	0.191	0.848	Rejected
H2	KA → BI	0.184	0.854	Rejected
H3	PC → BI	2.384	0.018	Accepted
H4	LC → BI	4.843	0.000	Accepted

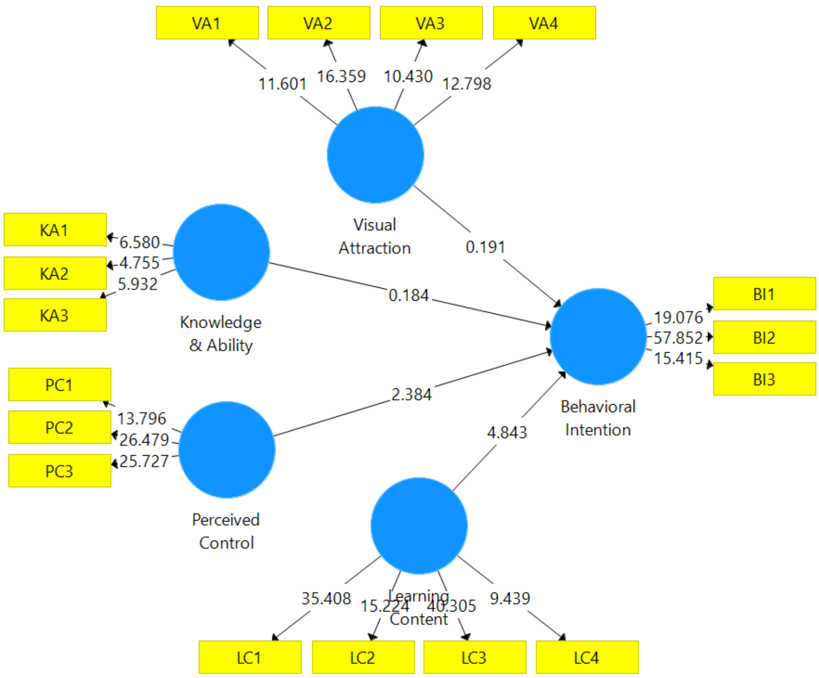

Figure 1. Measurement and model estimation

When it comes to R^2 measurement, this is an indicator of the value of predictive accuracy. The R^2 value at or greater than 0.75 is considered substantial, while the R^2 with a value of 0.5 is considered moderate or moderate, and if the value is 0.25, it can be categorized as weak [34]. The research results obtained are the variation of BI explained by VA, KA, PC, and LC, which is a substantial predictive level that is quite large. What's more, determining the effect size f^2 aims to determine if exogenous constructs significantly influence endogenous constructs. According to Hair *et al*. recommendations [29], the exogenous constructs' small, medium, and large effects on the endogenous constructs are represented by f^2 values of 0.02, 0.15, and 0.35, respectively. These research findings show that the f^2 values for VA, KA, PC, and LC variables are 0.00, 0.00, 0.03, and 0.13, respectively. Thus, PC has a small f^2 value, while LC has a large one. Finally, to determine the model fit index is determined through the normed fit index (NFI) and standardized root mean square residual (SRMR) values. The value of the former should be approaching 1.0, while the latter should be less than 0.10 [29]. The data obtained for the NFI and SRMR values are 0.69 and 0.08, consecutively. Based on these results, it can be implied that the measurement model has the criteria tested is fit.

5. DISCUSSION

Based on the four hypotheses proposed, H1 and H2 were rejected. This means that VA and KA do not significantly influence PSTs to adopt AR in science learning. Visual attraction may not be perceived as highly relevant to the educational goals of science learning. Pre-service teachers may place greater importance on factors such as content alignment, interactivity, and learning outcomes, while considering visual appeal as a secondary consideration. Moreover, PSTs may have realistic expectations of AR applications and prioritize functionality and usability over visual attractiveness. If they perceive that an AR application fulfils its educational purpose and is user-friendly, they may be more inclined to adopt it regardless of its visual appeal.

In terms of the knowledge-ability variable, this variable is indeed essential, whereas PSTs may prioritize their pedagogical skills. This resulted in them learning to integrate AR effectively into their teaching practice. Their focus may shift from technical knowledge to the application of AR as a pedagogical tool [37]. PSTs are taught how to integrate learning media in accordance with the learning objectives in the applicable curriculum [38]. Educational content and pedagogical aspects of AR applications over their visual appeal [39]. Their primary concern might be the effectiveness of AR in conveying scientific concepts and engaging students rather than the aesthetics of the technology [40].

In science learning, one important activity is hands-on experience [41], where PSTs more often use other more interactive technologies, such as virtual laboratories. This technology is readily available online, offering easy access to various experiments and simulations [42]. PSTs can use it at any time, enhancing the flexibility of their learning. Slightly similar to AR, virtual laboratories also provide high-quality visualizations, animations, and real-time data feedback [43]. These features facilitate a deeper understanding of scientific principles and enable PSTs to communicate complex concepts to students better. Thus, in terms of VA and KA, most tend to adopt other technology that is more attractive, but easier to use. This finding differs from Chen *et al*. [15] research, which identified VA and KA as significant influencing factors for students in design courses. In contrast, this study focuses primarily on pedagogical aspects, specifically pre-service science teachers. Therefore, in this context, the aesthetic and capability aspects do not appear to affect the adoption of AR in science learning significantly.

On the other hand, PC positively affects AR adoption among PSTs in science learning. This is because the ability to control AR technology allows them to tailor it to their pedagogical goals. They can adapt AR applications to align with specific curriculum objectives and teaching strategies [44], enhancing the learning experience. Furthermore, PSTs who perceive control may be more open to adopting innovative teaching methods. They are willing to experiment with AR as a novel educational tool, which can positively impact their teaching practices. In line with Krug *et al*. [45] research that implemented PST training in the competency area of simulation and modeling using AR technology. They found that PSTs' self-efficacy expectations related to AR technology increased significantly after the training, which suggests that PSTs are open to using AR technology in their teaching practices. This finding related to the significance of PC is reinforced by Saleem *et al*. [46] research, discovering that AR usage significantly influences e-learning behavioral intention.

Learning content is one variable with the highest significant effect compared to others, and it is analyzed based on *t*-value and p-value. In other words, AR has the capacity to make science content more engaging and interactive. It can transform abstract or complex scientific concepts into visually compelling, hands-on experiences, capturing students' interest and curiosity [47], [48]. PSTs recognize that AR can bridge the gap between theory and practical application, enhancing student engagement. Furthermore, AR technology aligns with the curriculum and is relevant to the educational goals, so PSTs are more likely to see the value in adopting AR as a teaching tool. Some science materials tend to be abstract, which encourages PSTs to use AR to help provide visualizations. Several empirical studies also agree that utilizing AR in science learning could enhance students' learning achievements [26], conceptual understandings [3], attitudes [49], and motivation [50]. This finding aligns with previous research [28], which states that learning content becomes the only variable that significantly affects undergraduate students' learning outcomes on particular simulation technology.

6. CONCLUSION

The factors that influence PSTs to adopt AR in science learning are visual attraction, knowledge-ability, perceived control, and learning content. However, only perceived control and learning content have a significant effect. This can be attributed to their alignment with effective pedagogy, educational impact, empowerment, and practical significance. PSTs prioritize factors that directly enhance their teaching practices and students' learning experiences, making perceived control and learning content the primary drivers of AR adoption, overshadowing the secondary importance of visual attraction and knowledge-ability.

As a suggestion, qualitative research can help uncover the nuanced reasons behind PSTs adoption decisions, shedding light on their perceptions and motivations in the context of AR in science education. This can unveil the reason for the insignificance of visual attraction and knowledge-ability variables. Teachers have a positive attitude toward AR training, despite the fact that training courses are not typically followed by practice for constructing and enhancing acquired knowledge, a positive attitude in digital technology, and a specific interest in AR technology. They also need technical training on AR media integration in learning. Thus, educational institutions and curriculum designers should work on aligning AR applications with the science curriculum to enhance relevance and educational impact. This research has practical implications, such as a teacher training program that can equip PSTs with the necessary knowledge and skills to integrate AR technology into their teaching practices effectively. The programs can be arranged through AR-related courses, so that they not only understand pedagogically but also technically.

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