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Exploring pre-service teachers' intentions of adopting and using virtual reality classrooms in science education

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Abstract

This study investigated how pre-service teachers perceive and plan to use a virtual reality classroom for science teaching during microteaching practices. The UTAUT 2 model was adopted as the conceptual framework for this study. Data were collected through an online survey from eighty-three pre-service science teachers from a large metropolitan university in Gauteng Province, South Africa. The collected data were analysed using descriptive and regression analysis. The results revealed that pre-service teachers demonstrated a high level of acceptance and intention to use Virtual reality classrooms in their microteaching practice and future classroom teaching. Thus, implying that they were receptive to the idea of using virtual reality classrooms in their microteaching practice and future classroom practice. Results further indicate that the preservice teachers are fascinated by the utilization of virtual reality classrooms for their microteaching practice based on two significant factors: social influence and technology self-assurance. However, results show that age and gender do not moderate the influence of performance expectancy, effort expectancy, social influence, facilitating condition, hedonic motivation, self-efficacy, anxiety and attitude on preservice teachers' behavioural intention to accept and the virtual reality classroom for their microteaching practice and future classroom teaching. The implications of these findings for science teaching and learning are discussed as it delves into the motivations and considerations of pre-service teachers when incorporating virtual reality classrooms into their teaching practices for science education.

Keywords Behavioural intentions · Microteaching · Pre-service teachers · Science education · Virtual reality classrooms

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1 Introduction

Virtual Reality (VR) has emerged as an innovative technology in various fields, including education. VR is an interface that immerses users in an artificial three-dimensional (3D) environment created by a computer or mobile device (Durukan et al., 2020). It combines elements of the real and virtual worlds, allowing for the creation of new environments where physical and digital objects can coexist and interact in real time (Cooper et al., 2019). Nonetheless, the simultaneous existence and interplay of these worlds can be observed through the utilisation of head-mounted eye goggles and wired attire, which enable the user to participate in authentic three-dimensional environments (Al Breiki et al., 2023). Research has demonstrated that VR technology offers the opportunity for individuals, irrespective of their position, geographical location, or economic circumstances, to partake in the educational process (Al-Amri et al., 2020; Shen et al., 2019). Hence, teachers are incorporating this innovative technology into classroom settings to instruct various academic disciplines, including the natural sciences, medical education, and science education (Broisin et al., 2017; Paxinou et al., 2020). In the context of science education, VR classrooms offer students a simulated environment where they can actively engage with scientific concepts and phenomena. These classrooms provide a platform for students to visualise abstract concepts and explore diverse scientific scenarios (Shen et al., 2019). By utilising VR classrooms in science education, students have the opportunity to delve into complex scientific theories, conduct experiments, and engage in hands-on learning experiences that would appear difficult to replicate in traditional classrooms. This in turn offers them a unique and immersive learning experience (August et al., 2016; Al-Amri et al., 2020). This immersive learning experience has the potential to enhance students' understanding, learning outcomes, attitudes, motivations, and interests in science (Arici et al., 2019; August et al., 2016; Al-Amri et al., 2020), making it an attractive option for pre-service teachers. Hence, incorporating VR classrooms into teaching practices can help teachers create dynamic and engaging learning experiences that foster students' interest and motivation to learn science.

The use of VR has been well-received by both students and teachers, as studies have shown a positive perception towards its adoption in the classroom (Al Breiki et al., 2023). As a result, teachers worldwide have begun embracing this technology to teach science subjects (Yang & Huang, 2021). Within the South African context, the utilisation of VR in teaching and learning is a relatively new concept primarily used for gaming and is still not as widespread as other educational technologies such as 3D simulations, videos and interactive smart boards (Homan, 2018). More importantly is the exposure of pre-service teachers (PSTs) to the use of VR classrooms during their microteaching practice.

The research reported in this article constitutes a part of a larger study on the use of a VR classroom to enable collaborative and contextualised microteaching practised by pre-service science teachers. Microteaching is a training strategy used to facilitate the acquisition of pedagogical skills by student teachers through engaging in short lesson presentations on a single, tightly defined topic (Banga, 2014). These short lesson presentations offer preservice teachers the chance to practice real teaching situations, helping them gain confidence and proficiency. Additionally, these focused teaching sessions are valuable tools for developing skills and preparing future teachers for their own classrooms. In the microteaching practice, preservice teachers teach microlessons in small group settings for a controlled duration of 5 to 20 min (Asare &Amo, 2023). This microlesson can be used in both online and face-to-face teaching settings. It allows preservice teachers to apply theoretical concepts from their training programs to real-world teaching scenarios. However, the emergence of simulated learning environments has prompted some universities to begin combining traditional micro-teaching methods with virtual or mixed-reality learning environments (Ledger & Fischetti, 2019). This innovative approach can assist preservice teachers in acquiring crucial technology integration skills and the mindset needed for the technologically advanced and dynamic future classrooms they will encounter in their teaching careers (Ledger & Fischetti, 2019). In light of this, it is essential to understand pre-service teachers' intentions in adopting and utilising virtual reality classrooms in science education. Particularly, this study aims to inform PSTs' use of VR for future science teaching by exploring the motivations and considerations of pre-service teachers when incorporating virtual reality classrooms into their microteaching practices. Several theories and models have been developed regarding the identification of the factors that impact users' acceptance of technology. The most significant among them is the Unified Theory of Acceptance and Use of Technology (UTUAT), which provides a comprehensive understanding of the determinants of technology acceptance. However, this study employs the UTUAT2 model, which is known for its strong predictive capability as demonstrated in the original study of the model (Venkatesh et al., 2012). This study is guided by the following two research questions:

> What is the level of acceptance and intention among pre-service science teachers towards utilising a virtual reality classroom for science teaching during their microteaching experience and in future classrooms?
> How do the UTUAT2 constructs impact the acceptance and behaviour intention to use Virtual Reality (VR) classrooms for science teaching during microteaching and in future classrooms among pre-service science teachers?

2 Literature review

In recent years, there has been a rise in the availability and usage of virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies across various fields (Cipresso et al., 2018; Yildirim et al., 2020). Augmented reality refers to a virtual environment that combines real surroundings with virtual objects, allowing users to interact with digital images in real time while observing the actual scene (Azuma, 1997). On the other hand, virtual reality is a computer-generated simulation of a three-dimensional environment that immerses users in a simulated learning environment, replicating real-life experiences using computer technologies (Martín-Gutiérrez et al., 2017; Yildirim et al., 2020). Mixed reality, on the other hand, encompasses a spectrum between a real scene and a fully immersed virtual environment (Milgram &

Kishino, 1994). Studies have indicated that incorporating modern technologies like virtual reality (VR) into science education has the potential to enhance the teaching and learning of physical concepts and phenomena that cannot be directly observed in daily experiences (Al-Amri et al., 2020; Al Breiki et al., 2023). The effectiveness of virtual reality (VR) classrooms in promoting scientific learning among pre-service teachers, as compared to other interactive technologies such as augmented reality (AR) or mixed reality (MR), lies in the complete immersion experience that VR offers. This enables pre-service teachers to actively participate in realistic and complex virtual environments, where they can simulate scientific phenomena, engage in practical activities, and observe scientific concepts within a controlled and secure environment (Yildirim et al., 2020). However, the acceptance and willingness of teachers to use VR technology, as well as their perception of its benefits for teaching and learning, play a crucial role in motivating and influencing their behaviour towards adopting this innovative technology in science teaching (Khukalenko et al., 2022). For instance, some factors that have been argued to influence how users perceive and accept e-learning and VR technologies include their confidence in using new technologies, their willingness to try new things, their anxiety about using new technologies, how much they enjoy using the technology, societal norms, the quality of the content and system, their previous experience with similar technologies, and the conditions that support their use (Jimenez et al., 2021). A recent study found that science teachers are more likely to have a positive attitude towards using virtual reality if they believe that it offers advantages over traditional teaching methods (Al Breiki et al., 2023). This positive attitude, however, depends on facilitating conditions such as the teachers' perceived readiness and confidence in using VR technology, which ultimately impacts their adoption of the technology in their teaching. Shen et al. (2019) conducted a study on how university students' intentions to use virtual reality for learning are influenced by the four constructs of the unified theory of acceptance and use of technology (UTAUT) model and the four modes of Kolb's learning styles. The authors discovered that the sampled students believed that using virtual reality head-mounted displays (VR HMDs) would enhance their learning effectiveness and academic performance, thus increasing their intention to use them. This intention was found to increase when students perceived VR HMDs as easy to use and when they had access to facilitating conditions like sufficient resources, convenient facilities, and infrastructure (Shen et al., 2019).

Research has indicated that there are certain factors that impact pre-service teachers' willingness to use technology. These factors include how useful teachers believe the technology is, how easy they perceive it to use, and their own confidence in using it effectively (Joo et al., 2018). These factors align with different layers of the virtual reality-enabled scientific experiment framework, which includes the visceral (emotional), behavioural, and reflective aspects of using technology in education (Xie et al., 2022). Bower et al. (2020) categorised factors that influence the intentions of pre-service teachers to utilise virtual reality in their classrooms into internal and design-related issues. Monteiro et al. (2022) argued that cultural factors play a role in the adoption of virtual reality for practical or experiential learning. For instance, the authors discovered that developed countries and regions tend to prioritise performance expectancy while developing countries focus more on effort expectancy when forming their attitudes towards new technologies like virtual reality. This difference may stem from variations in technological self-efficacy and availability of resources. Additionally, social influence and facilitating conditions were identified as significant contributors to positive attitudes towards virtual reality for practical learning. However, if users experience a high level of anxiety, including the fear of making mistakes and feeling apprehensive and intimidated about using virtual reality for practical learning, these positive attitudes or behavioural intentions may not be activated. Based on the result of the study, Monteiro et al. (2022) emphasise the importance of understanding these cultural factors to design and utilise virtual reality technology that can overcome cultural barriers or be tailored to specific cultural contexts.

3 Conceptual framework

The conceptual framework of this study is based on the Unified Theory of Acceptance and Use of Technology (UTAUT 2) model developed by Venkatesh et al. (2012). The UTAUT-2 model is an enhanced version of the UTAUT framework which is a comprehensive technology acceptance model (TAM) and combines various concepts from different models to assess technology use and acceptance. It integrates ideas from the TAM, the Diffusion of Innovations Model, the Theory of Reasoned Action, and other technology use models. The integration of these models allows researchers to study user behaviours and define outcomes based on previous research in the field. The UTAUT framework advocates that an individual's intention to use technology is influenced by factors such as performance expectancy (perceived usefulness of the technology), effort expectancy (perceived ease of use), social influence (appreciation of technology within the individual's social network) and facilitating conditions (availability of resources to use the technology). On the other hand, the UTAUT2 model proposes that in addition to these factors, intention to use technology is also influenced by hedonic motivation (perceived enjoyment of the technology), price/value (trade-off between perceived benefits and monetary costs), and habit (passage of time since initial technology usage), along with age, gender and experience as moderators (Venkatesh et al., 2012). Nevertheless, studies have indicated that the ability of the UTAUT model to predict the acceptance of technology can be improved by increasing the number of external variables (Wong et al., 2013). Consequently, several variables like self-efficacy, anxiety, satisfaction, perceived risk, and trust, have been recommended to complement the UTAUT2 model (Khalilzadeh et al., 2017).

According to the UTAUT2 model (Venkatesh et al., 2012), this study suggests that the intention of pre-service teachers to adopt virtual reality classrooms (VRCs) is influenced by several factors. These factors include performance expectancy, effort expectancy, facilitating conditions, social influence, and hedonic motivation. In this particular study, the virtual reality technologies used are owned by the institution, and the virtual reality classroom used is a free application designed by the institution and access to the application is freely provided to pre-service teachers. As a result, the "price value" construct is not applicable in this study. The students in this study are newly introduced to the use of VR technology and platforms. Hence, the "habit" and "experience" construct are not applicable either. Studies have highlighted the role of technological self-efficacy, anxiety and attitude on the acceptance and actual usage of systems (Pan, 2020; Schlebusch, 2018). Considering that the use of VR technology in teacher education programs, particularly in South Africa is still relatively new, understanding pre-service teachers' self-efficacy, anxiety, and attitude towards the use of such technology is considered very important for its adoption in microteaching practice and classroom teaching. Hence, the current study aimed to predict pre-service teachers' adoption of virtual reality classrooms (VRCs) by modifying the UTAUT2 model to include variables such as self-efficacy, attitude, and anxiety. Figure 1 shows the modified UTAUT2 model for the context of this study.

Based on the conceptual (modified UTAUT 2 model) applied in this study, there are 8 hypotheses and 16 sub-hypotheses. Table I shows the overall hypotheses that are tested using a two-tailed test with a 95% confidence level.

4 Research method

This study is based on quantitative research involving using the UTAUT2 survey developed by Venkatesh et al. (2003). The survey was administered using Google Forms to third-year pre-service science teachers at a large metropolitan university in Gauteng province, South Africa where advanced learning technologies are strongly embraced. The survey involved a specific selection of Eighty-three students who were enrolled in the teaching methodology and practicum module during their third

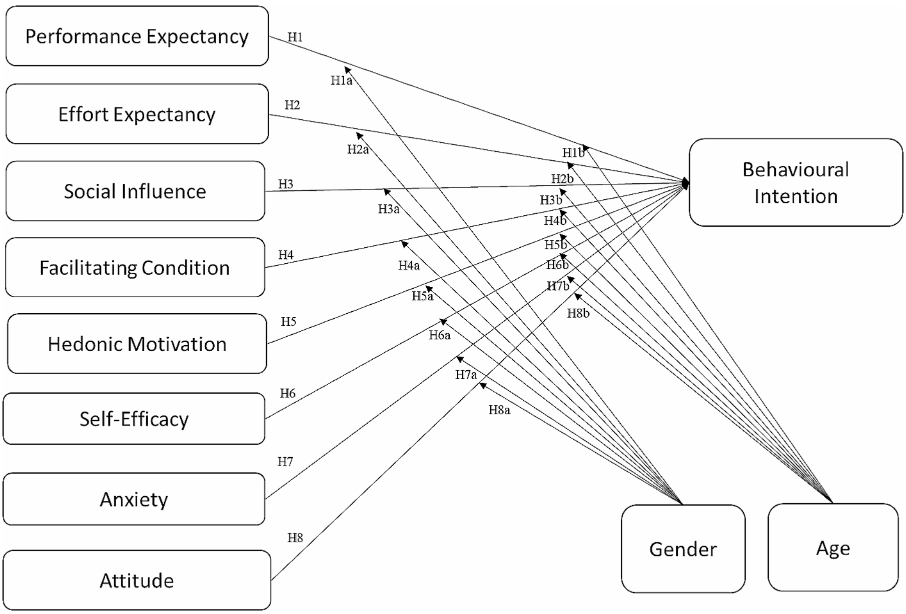

Fig. 1 Conceptual model of the study

Table 1 Hypotheses

	Hypothesis
H1	Performance Expectancy has a positive and significant influence on the intention to use VRC
H1a, b	The influence of Performance Expectancy towards intention to use VRC is moderated by Gender and Age
H2	Effort Expectancy has a positive and significant influence on the intention to use VRC
H2a, b	The influence of Effort Expectancy towards intention to use VRC is moderated by Gender and Age
H3	Social Influence has a positive and significant influence on the intention to use VRC
H3a, b	The influence of Social Influence towards intention to use VRC is moderated by Gender and Age
H4	Facilitating conditions have a positive and significant influence on the intention to use VRC
H4a, b	The influence of Facilitating Conditions on intention to use VRC is moderated by Gender and Age
H5	Hedonic motivation has a positive and significant influence on the intention to use VRC
H5a, b	The influence of Hedonic motivation towards intention to use VRC is moderated by Gender and Age
H6	Self-efficacy has a positive and significant influence on the intention to use VRC
H6a, b	The influence of self-efficacy towards intention to use VRC is moderated by Gender and Age
H7	Anxiety has a positive and significant influence on the intention to use VRC
H7a, b	The influence of anxiety towards the intention to use VRC is moderated by Gender and Age
H8	Attitude has a positive and significant influence on intention to use VRC
H8a, b	The influence of attitude towards intention to use VRC is moderated by Gender and Age

year. In addition, 42.2% were male and 57.8% were female. Of the participants, 95.1% were between the ages of 18–25, while 4.9% were between the ages of 26–30. Biographical information gathered shows that the sampled science students were from different areas of subject specialisation, which include Natural sciences and life sciences (9.6%), life sciences and physical sciences (34.9%), physical sciences and mathematics (12.0%), life sciences and mathematics (6.0%), life sciences and ICT support (2.4%), life sciences and Geography (20.5%), others (14.5%). Two lecturers who are also leading researchers in the field of science and technology education reviewed the adapted UTAUT2 instrument to make sure that every item was suitable for use in the actual study. The survey was employed as a baseline assessment in this study in order to collect data on how to guide and prepare students for the use of virtual reality before exposing them to the VR classroom experience. The survey administered consists of 34 statements arranged based on nine constructs (performance expectancy, effort expectancy, social influence, facilitating condition, attitude, hedonic motivation, anxiety, self-efficacy, and behavioural intention). The statements were answered by respondents on a five-point Likert scale ranging from ‘strongly disagree' (1) to 'strongly agree' (5). All respondents' inputs were recorded in an MS Excel table. Data was analysed using descriptive statistics, correlation analysis and multiple linear regression analysis using SPSS software.

5 Results and discussions

A Kaiser-Meyer-Olkin (KMO) test of sampling adequacy was performed to measure whether or not the sampling size was sufficient for factor analysis. Analysis shows that the KMO value was achieved at a value of 0.676 which is between 0 and 1, indicating that the sample is sufficient for factor analysis (Tabanick & Fidell, 2013). Similarly, Bartlett's test of sphericity was also conducted to measure the relationship between items. Findings reveal that $p < .001$ which is below 0.05, indicating that the sample has enough correlations between variables for factor analysis. Preliminary analysis to test the assumption of multicollinearity was also performed. The assumption for multicollinearity states that the variance inflation factor (VIF) values above 10 and tolerance value less than 0.10 indicate multicollinearity. However, the results showed that there were no violations of any of these assumptions because the VIF value is between 1.0 and 2.2, which is < 10, and the tolerance value is between 0.45 and 0.94, which is > 0.10. To investigate the presence of missing data across all variables, the Little's MCAR (missing completely at random) test was used. The test resulted in a chi-square value of 11.362 with 15 degrees of freedom and a significance level of 0.727, which is higher than the P-value of 0.05. This implies that the pattern of missing data is not completely random (MNAR). However, the value of missing data across the whole variable was less than 5%; as a result, excluded pairwise deletion approach was employed to handle the missing values in this study. Furthermore, the UTAUT2 survey was examined for face validity by a group of professionals composed of university teacher educators with science and technology education backgrounds and construct validity using factor analysis, as shown in Table 1. The Principal Component Analysis Extraction Method was used to analyse the factor on 34 items. The objective of the factor analysis was to determine whether the related items were grouped together under the same construct. The factor loadings for each item can be found in the Appendix. Results of the factor analysis show that only 9 factors were effective enough in representing all the 34 statements that were extracted from the analysis. According to Hair et al. (2012), the acceptable total variance explained by all components in factor analysis should be between 70 and 80% variance with a required minimum factor loading of 0.300. The contribution of each component (initial Eigenvalues percentage of variance) to the total amount of variance (70.83%) explained by the given principal component analysis is shown in Table 2. In addition, a reliability analysis was conducted for the constructs using Cronbach's Alpha. As summarised in Table 2, each of the dimensions appears to have a moderate to high degree of reliability since each computed statistic is above 0.50 (Hinton et al., 2014). Thus, indicating that all variables used in the measurement are reliable.

Table 2 Mean, standard deviations, validity, and reliability

Dimension	Number of items	Factor Range	Initial Eigenvalue Percentage of variance	Cronbach Alpha	Mean	Std Deviation	Level
Performance Expectancy	4	0.455 – 0.747	3.532	0.576	4.22	0.586	High
Effort Expectancy	4	0.534 – 0.707	4.158	0.761	3.89	0.609	High
Social Influence	4	0.627 – 0.700	5.856	0.805	3.98	0.677	High
Facilitating Condition	4	0.494 – 0.754	7.370	0.643	3.62	0.687	Moderate
Hedonic Motivation	3	0.764 – 0.871	9.835	0.882	4.54	0.517	High
Self-Efficacy	3	0.556 – 0.815	3.173	0.826	4.17	0.691	High
Anxiety	3	0.552 – 0.878	5.115	0.664	3.47	0.803	Moderate
Attitude towards using VR	4	0.527 – 0.800	3.121	0.794	4.36	0.684	High
Behavioural Intention	5	0.608 – 0.790	28.668	0.740	4.35	0.539	High
Overall					**4.08**	**0.643**	**High**

5.1 Level of acceptance and intention among pre-service science teachers towards utilising a virtual reality classroom for science teaching during microteaching practice

The acceptance and intention to use virtual reality classrooms for science teaching were categorised into three levels: low, moderate, and high, as proposed by Deris and Shukor (2019). According to their classification, a mean value ranging from 1.00 to 2.33 indicates a low level, 2.34 to 3.66 indicates a moderate level, and 3.67 to 5.00 signifies a high level of acceptance and usage (Deris & Shukor, 2019). Table 2 above also presents the specific levels of acceptance and intention for each construct related to virtual reality classrooms for science teaching, as well as the overall level of acceptance and intention. According to the data presented in Table 2, the average values for various factors related to the acceptance and intention to use virtual reality classrooms for teaching science were between 3.47 and 4.59. These values indicate a high level of acceptance and intention among pre-service science teachers. The only exception was anxiety and facilitating conditions, which had an average value of 3.47 and 3.62 respectively, suggesting a moderate level of acceptance and intention. Overall, the average value for all the factors combined was 4.08, indicating a high level of acceptance and intention to adopt virtual reality classrooms for teaching science in the future. Findings from this study showed that pre-service teachers rated hedonic motivation towards the use of VR classrooms highest and anxiety towards the use of VR classrooms lowest, which is similar to other technology acceptance studies (Bower et al., 2020). Nevertheless, results indicate that the sampled pre-service science teachers showed a high acceptance and intention to use virtual reality classrooms for science teaching. This is evident from the high average score of 4.35. The high willingness and intention demonstrated by sampled pre-service teachers might be attributed to their awareness and understanding of the significant emphasis placed by the South African government on prioritising technologies that can enhance teaching and learning in the fourth industrial revolution (4IR). Similarly, higher education institutions across the country are continually incorporating technology into teacher training, helping teachers stay up-to-date with the advances in technology that are changing teaching and learning practices and the world of work. This encourages teachers to make the most of these technologies for effective learning. The findings regarding the positive and high willingness of pre-service teachers to integrate VR classrooms in their future educational practice align with the findings of similar research studies (Cooper et al., 2019).

5.2 Influence of UTAUT2 constructs on the acceptance and behavioural intentions of pre-service science teachers to use virtual reality (VR) classroom for science teaching

Firstly, a Pearson correlation coefficient was calculated to ascertain significant relationships among the examined variables. According to Pallant (2016), the Pearson correlation coefficient value can indicate a small/weak relationship ($r = .10$ to 0.29), a medium/moderate relationship ($r = .30$ to 0.49) or a large/strong relationship ($r = .50$ to 1.0). Findings show that pre-service teachers' behavioural intention towards adopting and using virtual reality classrooms for science teaching was directly related to their performance expectancy, effort expectancy, social influence, facilitating condition, hedonic motivation, self-efficacy, anxiety and attitude with values between (0.30–1.00), all of which have statistical significance as shown on Table 3. Nevertheless, the results showed that the factor related to the participant's perceptions of the social influence has the strongest relationship ($r = .611$, $p < .01$) with teachers' behavioural intention toward adopting and using virtual reality classrooms for science education. In addition, the results showed that the factor related to the participants' anxiety has no relationship ($r = .136$, $p = .225$) with their behavioural intention towards using the virtual reality classroom for science. However, no significant relationships can be found between gender and age with respect to their hypothesised relationships with Performance Expectancy, Effort Expectancy, Attitude, Social Influence, Facilitating Condition, Hedonic Motivation, Self-Efficacy, and Anxiety.

A multiple linear regression test was used to determine the variable effect of UTAUT2 constructs: performance expectancy, effort expectancy, social influence, facilitating condition, hedonic motivation, self-efficacy, anxiety, attitude, gender and age on pre-service teachers' acceptance and behavioural intention to use virtual reality classroom for their microteaching practice and future classroom teaching. The significance of the model was examined using the analysis of variance (ANOVA). Results of the ANOVA show that the total F value (8.027) is statistically significant at p-value $< .001^{b}$. Thus, indicating that there is a statistically significant linear relationship in the regression model. Further analysis reveals that the coefficient of determination in the model summary is obtained at 0.538. This implies that 53.8% of the variance in pre-service teachers' intentions will be explained by the variation of the UTAUT2 constructs, while the remaining 46.2% will be explained by factors other than the independent variables not contained in the regression model as shown in Table 4.

Table 3 Correlation analysis for the various constructs

Constructs	1	2	3	4	5	6	7	8	9	10	11
1. Behavioural Intention	1	1									
2. Performance Expectancy	0.502**										
3. Effort Expectancy	0.451**	0.463**	1								
4. Social Influence	0.611**	0.469**	0.436**	1							
5. Facilitating Condition	0.396**	0.235*	0.476**	0.491**	1						
6. Hedonic Motivation	0.411**	0.508**	0.357**	0.363**	0.264*	1					
7. Self-Efficacy	0.520**	0.524**	0.387**	0.451**	0.445**	0.348**	1				
8. Anxiety	0.136	0.159	0.063	0.384**	0.388**	0.067	0.304**	1			
9. Attitude	0.569**	0.597**	0.412**	0.548**	0.318**	0.634**	0.432**	0.127	1		
10. Gender	0.157	0.159	−0.048	0.036	−0.032	0.024	−0.043	−0.006	0.086	1	
11. Age	−0.120	−0.079	−0.138	−0.107	−0.099	−0.042	−0.229*	0.090	−0.045	0.081	1

**. Correlation is significant at the 0.01 level (2-tailed).; *. Correlation is significant at the 0.05 level (2-tailed)

Table 4 Model summary

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Change Statistics				
					R^2 Change	F Change	df1	df2	Sig. F Change
1	.733[a]	0.538	0.471	0.392	0.538	8.027	10	69	<0.001

a Dependent Variable: BI; b Predictors: (Constant), How old are you? What is your Gender?

6 SI, ANX, EE, SE, HM, PE, FC, ATT

Findings from Table 4 also show the results of the calculated F value of 8.027 with a significant F less than 0.001 which is less than a p-value of 0.05 (5%), thus stating that all independent variables simultaneously affect pre-service teachers' behavioural intention. Further analysis show that social influence explains about 37.3% of the variance in behavioural intention, attitude accounts for 32.4%, self-efficacy explains around 27.0%, performance expectancy accounts for 25.2%, effort expectancy explains around 20.3%, hedonic motivation accounts for 16.9%, and facilitating conditions explains about 15.7% of the variance in behavioural intention as shown in Fig. 2.

In addition, the findings of the multiple linear regression analysis indicate that the social influence variable (SI) generated a t-value of 2.884, with a significance value of 0.005. Similarly, the self-efficacy variable (SE) produced a t-value of 2.058, with a significance value of 0.043. Since both variables have significance values of $p < .05$, this suggests that both variables positively and significantly influence the intention of pre-service teachers to use virtual reality classrooms for science teaching, as presented in Table 5.

Furthermore, Table 5 shows the significant factors that influence pre-service teachers' behavioural intention to use VRC for their microteaching and future classroom practice. The table also provides information on the feasibility of estimating the model, as well as an explanation of the independent variables used.

A separate hierarchical linear regression was used to determine if age and gender were moderating relations between preservice teachers' behavioural intention to use VRC and the various UTUAT2 constructs. Based on the stated hypotheses in Table 1, the null hypothesis is rejected if the calculated p-value in Table 5 exceeds 0.05, and the null hypothesis is not rejected if the p-value in Table 5 is within the 0.05 range. Based on the correlation and regression analysis, the result of the hypotheses testing shows that only social influence ($\beta = 0.341$; $p < .05$) and self-efficacy ($\beta = 0.217$; $p < .05$) had a positive and significant influence on preservice teachers behavioural intention to accept and use Virtual reality classroom for their microteaching practice and future classroom teaching, supporting H3 and H6. The result of the hypothesis testing also demonstrate that performance expectancy ($\beta = 0.069$; $p = .540$), effort

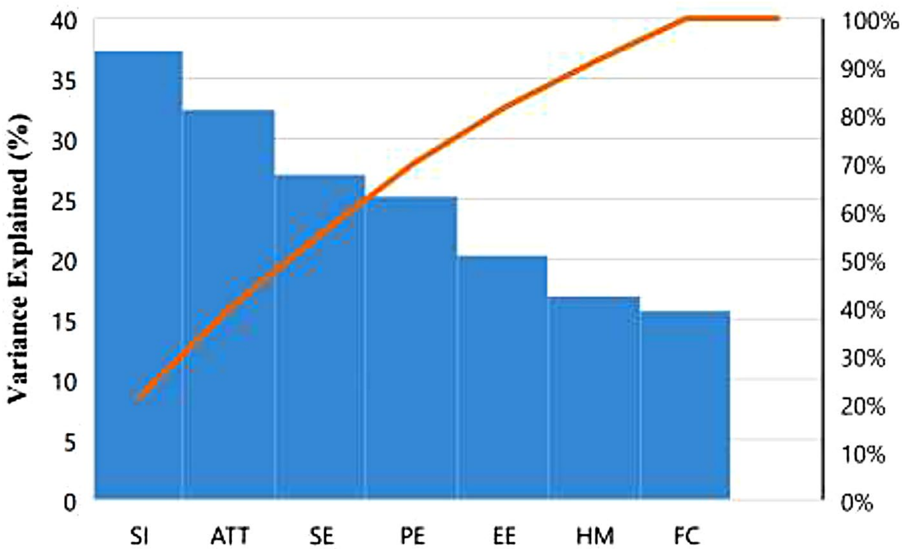

Fig. 2 Percentage of variance explained in behavioural intention by each UTUAT2 variable

Table 5 Multiple Linear Regression Analysis

Model	Unstandardized Coefficients		Standardised Coefficients	T value	P value
	B	Std. Error	Beta		
Constant	1.121	0.496		2.261	0.027
Performance Expectancy	0.063	0.102	0.069	0.616	0.540
Effort Expectancy	0.093	0.094	0.106	0.990	0.325
Attitude	0.108	0.096	0.137	1.121	0.266
Social Influence	0.271	0.094	0.341	2.884	0.005
Facilitating Condition	0.052	0.087	0.067	0.605	0.547
Hedonic Motivation	0.060	0.115	0.057	0.519	0.605
Self – Efficacy	0.169	0.082	0.217	2.058	0.043
Anxiety	−0.089	0.067	−0.132	-1.320	0.191
Gender	0.114	0.091	0.105	1.248	0.216
Age	0.002	0.023	0.009	0.106	0.916

a Dependent Variable: BI

expectancy (β=0.106; p=.325), facilitating conditions (β=0.067; p=.547), hedonic motivation (β=0.057; p=.605), and attitude (β=0.137; p=.266) had a positive but insignificant influence on preservice teachers behavioural intention to accept and use VR classroom for their microteaching practice and future classroom teaching, hence H1, H2, H4, H5, and H7 were not supported. In terms of the moderating effect, results show that age and gender did not exhibit significant ($p>.05$) interactions with any of the constructs when considering all possible higher-order interactions. Hence, hypotheses H1a, H1b, H2a, H2b, H3a, H3b, H4a, H4b, H5a, H5b, H6a, H6b, H7a, and H7b in Table 1 were not supported. The equation of the multiple linear regression model that was generated is as follows:

Behavioural Intention = 1.121 + 0.271 Social Influence + 0.169 Self Efficacy + e.

The regression equation model shows that the variables: social influence (X1) and self-efficacy (X2) are positive. A summary of the output analysis is illustrated in Fig. 3. However, it should be noted that non-significant variables are not shown in the figure.

The multiple linear regression equation suggests that pre-service teachers are confident in their ability to use virtual reality classrooms and that there is a positive relationship between their perception of social influence and their intention to use VR technology in their future educational practices. Hence, we can conclude that if their perception of the social influence variable decreases (not maintained) and the self-efficacy variable is also low, then pre-service teachers' acceptance and intentions in using VR classrooms will tend to be lower. The results suggest that pre-service teachers' intentions to adopt the VR classroom is not only dependent on the level of confidence they possess in their ability to effectively utilise technology but also on their personal perception of the opinions held by individuals within their environment or social pressure exerted by various sources such as leadership figures, students, teach-

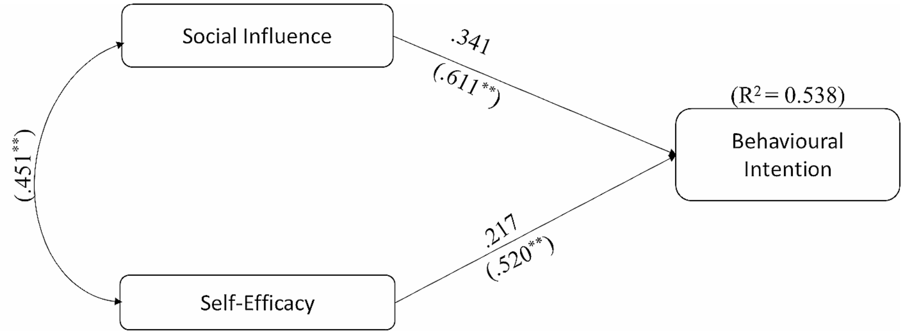

Fig. 3 Results of the output analysis

ing staff and other factors that motivates them to use the virtual reality classroom (Wang & Wang, 2009). Therefore, in order to ensure the practicality and long-term viability of incorporating virtual reality classrooms into the teaching methods of pre-service teachers, it may be necessary for institutions to develop clear and comprehensive policies and guidelines that outline the purpose, scope, and acceptable use of VR. Communicating these policies to all stakeholders, including pre-service teachers, faculty, and administrators, can make the use of VR classrooms a feasible option for pre-service teachers and have a significant impact on their decision to integrate VR into their teaching practices. If expectations regarding the use of VR technologies in institutions are clearly defined, it can create a sense of normalcy around the use of VR classrooms and can encourage continued implementation.

6.1 Limitations

The limitations of this study include the fact that the VR classroom used was developed within a specific model-based learning approach at a particular public South African university. However, the researchers believe that the findings can still be valuable for other private and public South African universities looking to incorporate VR into science teacher preparation. Furthermore, it is important to note that the UTAUT2 model does not take into consideration the potential impact of cultural differences on the adoption of virtual reality in education. Therefore, future research could explore the adaptation of the UTAUT2 model to qualitatively explore how cultural factors such as access to technology and diverse linguistic, cultural, and socioeconomic factors influence the acceptance, relevance and applicability of VR in education in South Africa. Another limitation of this study is the absence of assessment on pre-service teachers' previous experience with virtual reality (VR) since the purpose of the survey was to establish a baseline on their intention to incorporate VR into their microteaching experience. As a result, it is assumed that the pre-service teachers have not experienced the VR application, even though it is possible that they are aware of its use in education. Since this study is part of a larger research project exploring the use of VR classrooms, further investigation is needed to determine if pre-service teachers' intentions to integrate VR into their future classrooms actually changed after the opportunity to experience the use of VR during their microteaching practice. Nevertheless, there is potential for teacher education programs and school systems to take advantage of the interactivity and immersive experience provided by VR technology, as it can help address any anxiety or concerns pre-service teachers may have about using virtual reality technology, allowing them to feel comfortable and confident in its use, as well as develop a positive attitude towards using virtual reality technology in their future classrooms, ultimately improving their behavioural intention towards its use and adoption.

7 Conclusion

This study contributes to the existing body of knowledge on how pre-service teachers' willingness to utilise virtual reality (VR) classrooms for science instruction is influenced by various essential factors related to the acceptance and the use of technology. According to the findings of this study, pre-service teachers demonstrated a high level of intention towards utilising virtual reality classrooms for their microteaching practice and in their future careers. However, their intentions were found to be mostly influenced by their perceived social pressure and self-efficacy towards the use of VR technology. This implies that the opinions and suggestions of important and prominent people can serve as a driving force for pre-service teachers' adoption and use of virtual reality classrooms for their micro-teaching practice. This result is in line with previous studies that have shown how technology users are greatly influenced by the opinions of others within their social circle (Venkatesh et al., 2012; Al Breiki et al., 2023). Additionally, the research findings showed a direct effect of technology self-efficacy on behavioural intention, indicating that pre-service teachers' acceptance to use and adopt VR classrooms for microteaching and in their future classrooms is influenced by their confidence in their ability to use technological tools.

Unlike the findings of Venkatesh et al. (2012), the results of this study suggest that pre-service teachers' intentions to use virtual reality classrooms were not significantly related to their perceptions of expected outcomes, perceived effort, hedonic motivation, attitude, anxiety, or facilitating conditions. This suggests that the UTUAT2 model may not fully explain pre-service teachers' willingness to adopt and use VR classrooms for their microteaching and future classroom practice. However, the study still found a direct association between pre-service teachers' behavioural intention and the UTAUT2 variables, except for anxiety, gender and age. This implies that these factors are still relevant and impactful in understanding pre-service teachers' willingness to adopt and use virtual reality classrooms, even if they are not direct predictors of behavioural intention. To effectively prepare pre-service teachers for the adoption and use of virtual reality classrooms, teacher education programs need to prioritize enhancing their perceptions of expected outcomes, perceived effort, hedonic motivation, attitude, and facilitating conditions during the planning stage of implementing the VR technology. The results of this study indicate that in order to increase the use of virtual reality classrooms among pre-service teachers, higher education institutions need to create training programs that prioritize improving social influence. This can be achieved by including activities such as peer learning, collaboration, and mentorship programs, where pre-service teachers can learn from their peers or experienced educators who have a positive impact on their perception of using VR. In addition, it is important to design immersive and interactive experiences for pre-service teachers to engage with VR technology, as this can greatly enhance their self-confidence and self-efficacy through hands-on engagement with the technology. Alleviating pre-service teachers' anxiety before exposing them to the VR classroom is also crucial in optimizing their experience. According to McGarr (2021), virtual reality environments provide pre-service teachers with unique opportunities to experience examples of classroom life in a controlled manner, which thereby enhances their classroom behaviours and management skills. Hence, promoting the benefits and affordances of using VR classrooms more than traditional teaching methods can help improve pre-service teachers' attitudes towards its adoption and use. Furthermore, providing organizational and technical infrastructure that can make the use of VR tools visible in schools can also help pre-service teachers develop a better attitude towards its adoption and use.

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Data availability The authors collected the data that support the findings of this study. Although the data are not publicly available due to ethical restrictions, they can be obtained from any of the authors upon reasonable request.

Declarations

Conflict of interest No potential financial or professional conflicts of interest were reported by the author(s).

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