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Investigating science teachers' intention to adopt virtual reality through the integration of diffusion of innovation theory and theory of planned behaviour: the moderating role of perceived skills readiness

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Abstract

This study contributes to the extant literature on instructional technology by investigating the relationships between the social and personal factors and behavioral intention to use virtual reality. Moreover, the current study examined the links between perceived characteristics of virtual reality and attitude and the moderating role that can be played by perceived skills readiness between those links. Inspired by the Theory of Planned Behaviour and Diffusion of Innovation Theory, a set of hypotheses was formed to test the proposed relationships using structural equation modeling partial least square to a sample of 171 science teachers in Oman. The results showed that attitude, social norms and perceived behavioral control can predict behavioral Intention to use virtual reality with attitude as the strongest predictor. Furthermore, the results indicated that relative advantage could predict attitude towards using virtual reality while compatibility and observability cannot. Finally, perceived skills readiness can strengthen the relationship between the perceived characteristics of virtual reality applications (relative advantage, compatibility and observability) and attitude towards using the virtual reality in the science classroom. Thus, this study highlights the importance of focussing on science teachers' skills readiness to use virtual reality so that they can use it confidently. Implications and future research studies are discussed.

Keywords Diffusion of Innovation Theory · Theory of Planned Behavior · Virtual reality · Behavioural intention · Perceived skills readiness

Extended author information available on the last page of the article

1 Introduction

The advancement of modern technology has influenced many sectors around the world. Education is not isolated from this development as technology facilitates educational practices for both teachers and students. Raja & Nagasubramani (2018) and (Kamińska et al., 2019) highlighted the importance of modern technology in terms of its embedment in the school curriculum, a mechanism of assisting with instruction, and a tool to improve the overall learning process. Nowadays, instructors' teaching strategies and technologies have developed from conventional methods and technologies to the most advanced ones. Virtual Reality (VR) is one of the modern technologies that are a counterpart to natural reality which is experienced in the real world (Yoh, 2001). Steuer, (1992) indicated that VR refers to digital simulations of the worlds that are viewed using head-mounted eye goggles and wired clothing, allowing the end-user to engage in genuine three-dimensional settings. VR is distinctive from other technologies as it allows for exceptional visualization, which is impossible to achieve in a regular classroom setting (Kamińska et al., 2019). Moreover, this technology allows everyone, from anywhere, to engage in the educational process, regardless of position or financial status (Ally, 2019; Kamińska et al., 2019).

Therefore, instructors prefer to adopt this technology in classroom contexts to teach different school subjects such as language learning (Lan, 2020), physical geography, medical education (McGrath et al., 2018), and science education (Liou & Chang, 2018). Research has indicated that VR has a significant impact on student's performance in different school subjects (Allcoat & von Mühlenen, 2018). VR technology usage is highly encouraged to be implemented in the online environment where students are not able to join face-face environments (Joshi et al., 2021; Mystakidis et al., 2021). For instance, it can help to expand access to virtual laboratories for teaching science in terms of doing experiments as if they were in a classroom setting (Martín-Gutiérrez et al., 2017).

Students have a positive perception of its adoption in the classroom context (Fagan et al., 2012). Therefore, instructors around the globe have started to adopt this technology to teach science subjects via online mode as schools have been locked down because of the coronavirus outbreak (Yang & Huang, 2021). However, in the Omani context, the adoption of VR is still limited in comparison to other types of educational technologies that have been used by science teachers such as videos and interactive smart boards (Ministry of Education, 2021). Based on that, it is crucial to investigate the factors that contribute to the lack of adoption of this technology by Omani teachers. Alfalah (2018) conducted a study about VR and claimed that factors that influence the adoption of VR need more investigation. In previous studies, factors such as behavioral beliefs, normative beliefs and control beliefs might have either positive or negative impacts on the intention of virtual environment adoption (Kennedy-Clark, 2011; Mazman Akar, 2019). Other studies revealed some factors such as compatibility and perceived ease of use that might increase the intention to use virtual learning systems (Mamat et al., 2015).

Research has indicated that VR technology and its applications have been intensively studied in terms of the factors that contribute to its adoption and acceptance using well-known theories and models such as the Theory of Planned Behaviour

(TPB), and diffusion of innovation theory (DIT). Most studies have adopted TPB (Alzahrani et al., 2017; Kennedy-Clark, 2011), and IDT (Nuanmeesri & Poomhiran, 2019; Tiwari & Damle, 2020) separately. However, there is a lack of studies that employ both theories in investigating VR adoption by science teachers. Therefore, this study aims to examine the factors affecting VR adoption while teaching online in Cycle 2 and post-basic education by integrating diffusion of innovation theory (DIT) and the theory of planned behavior (TPB) in one model.

2 Theoretical background and hypotheses formulation

Overall, Predictive studies seek to find the best ways to predict the chances of success in productivity in the work environment. Given the complexity of the process of predicting human behavior and the futility of relying on one theory for the success of this process, the method of merging multiple theories resorted to come up with a more comprehensive understanding and achieve the goals of the prediction process (Ahmad & Ahmed, 2020).

Accordingly, this study seeks to investigate the predictive ability of the proposed model when integrating the constructs of the diffusion of innovation theory (DIT) and the constructs of the theory of planned behavior (TPB) to examine the factors that may affect teachers to adopt virtual reality applications in the teaching process. The theory of planned behavior (TPB) has been employed in many fields concerned with behavior, as it has proven its worthiness as an effective theory for guiding the design of an intervention to change behavior. This theory has many advantages that distinguish it to be the optimal model for predicting and changing behavior (Ajzen, 2020). The reasons for selecting TPB is that this theory considers the social factors through integrating social norms to the model, however, TAM proposed by Davis (1989) does not include a social factor as a main component in the model. In addition, although UTAUT developed by Venkatesh et al., (2003) contains social influence as a main component in the model, it lacks the attitude variable. However, attitude is considered a major factor in determining the behavioral intention of using a particular technology. The second reason for using TPB is that TPB assumes that individuals have volitional control over their intentional behavior and this could be because of the availability of the resources which includes ability, time, information and money (Ajzen, 1991). In this study science teachers can use virtual reality voluntary, and nobody can force them to use this technology. However, TAM and UTAUT are unable to explain non- volitional control over the individuals' behaviors.

On the other hand, the innovation diffusion theory (DIT) has proven to be successful in many areas, especially in the field of education, where it continues to play an important role because it can provide an answer to how societies respond emotionally and behaviourally towards innovations (Hains & Hains, 2020). We used this theory to introduce the characteristics and attributes that may affect the attitudes of using virtual reality as literature shows that they may have a direct impact on attitudes of individuals as explained in the next sections, however, UTAUT does not have the attitude variable.

In general, the adoption process is complex and requires a lot of research and effort to study and track its effects on humans. Hence, it is necessary to use and employ these theories as a frame of reference to form a greater and broader understanding of the rate of adoption of virtual reality technology among teachers by tracking the characteristics identified by (DIT), namely: Compatibility, Observability, and Relative advantage. Then, researchers should trace the overall effect of these characteristics on Perceived attitudes, which represents one of the considerations that guide human behavior in TPB.

2.1 Attitudes and behavioral intention

Behavioral intention refers to the willingness of a person to perform a particular behavior (Ajzen, 1991). It is also considered a cognitive factor that is affected by several antecedents such as attitude, subjective norms and perceived behavioral control. These three predictors are the main factor that influences behavioral intention directly in this study. Attitude toward behavior refers to the beliefs of a person about a target behavior (Ajzen, 1991). Individuals hold several behavioral beliefs that contribute to linking behavior with the expected outcome. This is what is described in the theory of planned behavior as a person's attitude (Ajzen, 2020). According to Zhang et al., (2013), these beliefs have a direct impact on the steps of the adoption process within individuals. This is what the current study seeks to prove in the way teachers adopt virtual reality in the teaching process. In light of the foregoing discussion, the first hypothesis of the current study assumes that there is a positive correlation between attitudes toward virtual reality adoption and behavioral intentions. Islam et al., (2013) confirmed and supported the existence of this positive relationship.

H1: Attitude is positively associated with behavioral intention.

2.2 Subjective norm

Subjective norm refers to the perceived social pressure that may be exerted by significant people in people's lives (Ajzen, 1991). The individual is subject to a fabric of subjective normative beliefs that are developed according to what he believes to be the expectations of important individuals in his life. These expectations are represented in the form of personal standards that motivate the individual to adopt a new behavior in his life (Ajzen, 2020). However, in the current study, subjective norm represents the pressure that is applied by colleagues, senior teachers, supervisors or headmasters in the adoption of virtual reality. Many studies have indicated that subjective norm has as an impact on individuals' adoption of new behaviors and their personal lives (Shalender & Sharma, 2021; Wan et al., 2017). The current study seeks to prove the positive impact of this construct on science teachers which can push them to adopt virtual reality applications in the science teaching process.

The current research, in its second hypothesis, examines the existence of a positive association between subjective norms and behavioral intentions. In their study, Alqasa, Mohd Isa, Othman, and Zolait (2014) and Lee & Tanusia (2016) confirmed the existence of this positive association between the two variables.

H2: Subjective norm is positively related to behavioral intention.

2.3 Perceived behavioral control

Another important construct in the TPB is perceived behavioural control. This construct denotes the person's perception of the difficulty and ease of executing a particular behavior (Ajzen, 1991). The theory of planned behavior assumes that individuals hods control beliefs that are related to their perceptions that may hinder or facilitate the performance of that behavior (Ajzen, 1991, 2020). The results of several studies support the existence of the positive effects of perceived behavioral control on individuals' adoption of different applications and technologies (Lee & Kozar, 2008; Yitbarek & Zeleke, 2013). The current study assumes the presence of the same positive effect of perceived behavioral control on teachers' behavior in their adoption of virtual reality applications in education. The third hypothesis of the current study examines the correlation between perceived behavioral control and behavioural intentions, and assumes that there is a positive relationship between the two variables, In their study, Aitken et al., (2020) confirmed the existence of this positive association between the two variables.

H3: Perceived behavioural control is positively associated with behavioural intention.

2.4 Compatibility

Compatibility, as defined by Rogers (1995), is the extent to which the innovation is well-matched with the adopter's values, habits, and beliefs and does not conflict with innovation (Rogers, 1995; Jwaifell & Gasaymeh, 2013; Min et al., 2019)noted an effect of conformity on adoption among individuals. Research evidence proves the correlation between compatibility and teachers' intention to adopt virtual reality applications in the educational process (Au & Enderwick, 2000; Mairura et al., 2016). Precisely, several studies reported a positive direct influence of compatibility on behavioral intention and perceived attitude (Folorunso et al., 2010; Jiang et al., 2021; Ntemana & Olatokun, 2012; Sharif et al., 2017). However, Waheed et al., (2015) noted a negative effect of compatibility on the technology users' behavioral intention and perceived attitude. In this study, we expect a positive effect of compatibility on the teachers' intention and attitude to adopt virtual reality in teaching. Hereby, the study seeks to verify the following assumptions:

H4: Compatibility is positively associated with behavioral intention.

2.5 Relative advantage

Diffusion of Innovation Theory assumes that the adoption process is directly related to the individual with the comparative advantage of any innovation (Rogers, 1995). Several studies indicated a direct effect of the relative advantage of technology on users' perceived attitude (Chibuogwu et al., 2021; Min et al., 2019). Yet, Ashinze et al., (2021) observed an indirect influence of relative advantage on the perceived attitude. However, Awe & Ertemel (2021)found no effect of relative advantage on attitude and behavioral intention. Based on these findings, we assume a direct positive effect of relative advantage on perceived attitude. We, therefore, hypothesize that:

H5: Relative advantage is positively associated with perceived attitude.

2.6 Observability

Observability is the degree to which the results and benefits of innovation be observed and more likely to be adopted by potential users (Rogers, 1995). Previous studies have indicated a positive effect of observability on the behavioral intention to adopt a technology tool (Ali et al., 2019; Pashaeypoor et al., 2016). Other studies have asserted a positive relationship between observability and attitude (Park & Chen, 2007). This suggests that the more benefits from the used technology observed, the more likely this technology is to be adopted. However, studies like Ahn & Park (2022) and Qazi et al., (2018) found no association between observability and attitude. The current study seeks to prove the following:

H6: Observability is positively associated with perceived attitude.

2.7 Perceived skills readiness (PSR) as a moderator

Much research devoted to integrating technology in education indicates that the efficiency of this practice relies on the beliefs and skills that teachers perceive towards technology (Badia et al., 2014; Hermans et al., 2008; Mutambara & Bayaga, 2021). Perceived skills readiness (PSR) is defined, from the teaching perspective, as the teacher's perception of his or her competency to apply technological tools in an online setting for teaching a particular topic (Al-Maroof et al., 2021). It helps teachers to adopt innovative online learning resources and multimedia assets or models to promote the quality of learning. Data from several studies have revealed that the level of PSR that one demonstrates is a significant predictor of his or her attitude toward using technological tools (Alakrash et al., 2021; Kee & Samsudin, 2014; Mutono & Dagada, 2016; Rhema & Miliszewska, 2014; Sánchez-Cruzado et al., 2021).

Having a high level of skills readiness helps technology users to develop a positive attitude toward technology and thereby lessen anxiety and frustration (Mutono & Dagada, 2016). Similarly, people with adequate technology skills show a great level of motivation and satisfaction as they run technological tools effortlessly (Kee & Samsudin, 2014). In contrast, there is research evidence revealing that teachers have low self-perception toward their skills readiness in online education (Sánchez-Cruzado et al., 2021; Helsper & Eynon, 2013) explain that high levels of skills readiness help users to enrich and further understand their use of technology, whereas those with low levels of skills readiness struggle to engage themselves in technology. Therefore, there is a significant positive relationship between perceived skills readiness and the attitude toward the use of digital technologies (Abima et al., 2021).

H7: The relationship between perceived attitude and compatibility is strong when perceived skills readiness is high.

H8: The relationship between perceived attitude and relative advantage is strong when perceived skills readiness is high.

H9: The relationship between perceived attitude and observability is strong when perceived skills readiness is high.

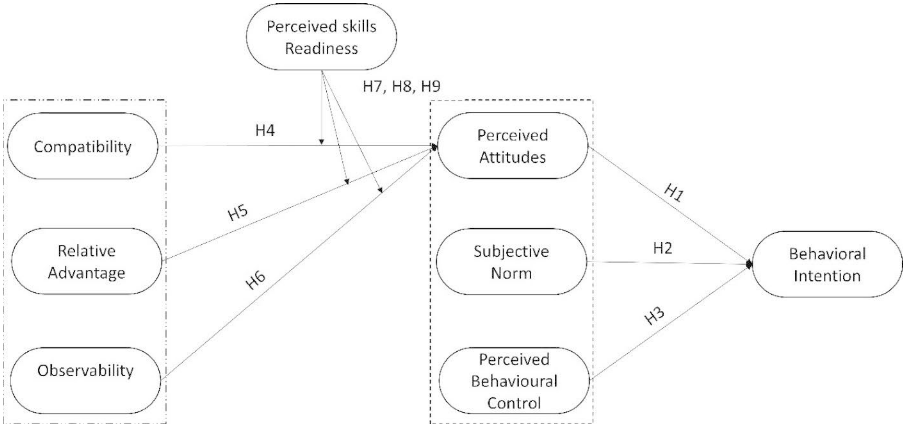

Fig. 1 Theoretical framework

3 Method

3.1 Research design

The current study uses a structural equation modeling (SEM) approach to develop a model that integrates Diffusion of Innovation Theory (DIT) and Theory of Planned Behaviour (TPB) to predict and explain science teachers' intention to use virtual reality in teaching. The proposed model tests the relationship between perceived skills readiness (PSR) and the five variables of the study which are attitude (ATT), subjective norm (SN), perceived behavioral control (PBC), observability (OB) and relative advantage (RA).

3.2 Sampling and data collection

The study was derived from primary data gathered from a total of 171 science teachers employed in public schools across Oman. The gender breakdown was 41.9% male and 58.1% female. 73.3% of the participants had a teaching experience of more than 7 years, whereas 5.8% had less than two years of experience. The majority of the participants (75.6%) revealed that they have exposed virtual reality training while they are in-service as science teachers (Table 1).

3.3 Research instrument

The data was collected using a questionnaire developed to predict the intention of science teachers in adopting virtual reality in their teaching (See the Appendix). The questionnaire included the constructs of the proposed model which are Attitude (ATT), Behavioural Intention (BI), Subjective Norm (SN), Perceived Behavioural Control (PBC), Compatibility (COMP), Relative Advantage (RA), Observability (OB), and Perceived Skill Readiness (PSR). The factor measurement scale employed

Table 1 Demographic information of the sample

Variables	*Number (N)*	*Percent (%)*
Gender		
Male	72	42.1
Female	99	57.9
Subjects		
Sciences	29	17
Physics	50	29.2
Chemistry	46	26.9
Biology	43	25.1
Science and Technology	2	1.2
Science and Environment	1	0.6
Stage		
Cycle 2	87	50.9
Cycle 3	84	49.1
Years of Teaching Experience		
Above 10 years	125	73.1
6–10 years	23	13.5
2–5 years	13	7.6
Below 2 years	10	5.8
Have you exposed to virtual reality training before?		
Yes	129	75.4
No	42	24.4
Total	171	100.00

Table 2 Full Collinearity Test

Constructs	BI	COMP	OB	ATT	PBC	PSR	RA	SN
VIF	4.391	3.984	3.840	3.452	2.945	2.882	4.458	3.108

Table 3 Correlation between constructs

	BI	COMP	OB	ATT	PBC	PSR	RA	SN
BI								
COMP	0.744							
OB	0.712	0.719						
ATT	0.802	0.681	0.641					
PBC	0.613	0.626	0.67	0.413				
PSR	0.628	0.681	0.711	0.532	0.721			
RA	0.754	0.819	0.769	0.742	0.544	0.615		
SN	0.727	0.694	0.742	0.606	0.678	0.578	0.674	

in this questionnaire was a Likert scale of 5 points (from “Strongly disagree” to “Strongly agree”), except for Behavioural Intention (BI) which included 7 points.

The questionnaire items were adapted and modified from previous studies to suit virtual reality in teaching sciences subjects (See the Appendix). After the adaptation, the questionnaire was piloted to 37 science teachers and the Cronbach alpha was cal-

Table 4 Factor loadings

Constructs		Factor loadings	Composite Reliability	Cronbach's Alpha	(AVE)
BI	BI1	0.846	0.894	0.926	0.759
	BI2	0.915			
	BI3	0.82			
	BI4	0.901			
COMP	Comp1	0.935	0.897	0.936	0.830
	Comp2	0.938			
	Comp3	0.858			
OB	Observ1	0.782	0.819	0.881	0.651
	Observ2	0.853			
	Observ3	0.866			
	Observ4	0.717			
ATT	PA1	0.907	0.932	0.951	0.83
	PA2	0.922			
	PA3	0.901			
	PA4	0.915			
PBC	PBC1	0.818	0.863	0.893	0.586
	PBC2	0.820			
	PBC3	0.815			
	PBC4	0.814			
	PBC5	0.708			
	PBC6	0.586			
PSR	PSR1	0.907	0.890	0.932	0.82
	PSR2	0.925			
	PSR3	0.885			
RA	RA2	0.949	0.940	0.961	0.893
	RA3	0.935			
	RA4	0.950			
SN	SN1	0.826	0.825	0.893	0.736
	SN2	0.893			
	SN3	0.853			

culated. The Cronbach alpha output indicates that all constructs in the questionnaire were acceptable.

3.4 Data analysis

To examine the relationships between the variables in the proposed model, the researchers used partial least squares structural equation modeling (PLS-SEM) using SmartPLS 3.

The reasons for using SEM to analyze the data as follows (Hair et al., 2016). First, it follows rigorous procedures to analyze the data. Second, compared to traditional methods such as regression, SEM is capable of assessing or correcting measurement errors of the model. Third, traditional methods use observed variables but SEM can use both latent (unobserved) and observed variables in the same model. Finally, SEM can test relationships in one complete model. Regarding using PLS-SEM to test the hypothesis, it was employed in this study for three reasons. First, PLS can handle incremental studies, as in the current study, where new constructs and new paths are added to an existing model (Chin, 2010). Second, PLS-SEM is appropriate when introducing new moderators to the model (Becker et al., 2018; Sarstedt et al., 2020). Third, PLS-SEM is can handle complex models with more than eight constructs (Hair et al., 2016).

4 Results

4.1 Preliminary analysis

Before testing the model, the researchers examined the multivariate normality of the collected data using WebPower. Specifically, they used Mardia's coefficient procedure. The results indicated that the kurtosis coefficient is 123.137. This result confirmed that the data is not normally distributed as the kurtosis coefficient score should not exceed 20 (Byrne, 2013; Kline, 2015), hence, the researchers suggested using PLS-SEM because it is an appropriate statistical inferential technique for handling non-normality distributed data.

4.2 Common method variance (CMV)

Since the dependent variable and independent variables were collected using a single-source instrument, CMV or common method bias should be addressed as suggested by (Podsakoff et al., 2003, 2012). In the current study, the researchers firstly employed different anchor scales for the dependent (7 Likert-scale) and independent variables (5 Likert-scale) as a procedural remedy. Second, the researchers used three statistical remedies to tackle the CMV problem. First, Harman's single factor test was used and it was found that a single factor explained 50.943% of the variance which is a little bit above the threshold (50%) suggested by Podsakoff et al., (2003). Second, the full collinearity test was examined and it showed that all the values of variance inflation factor VIF are less than 5 which is recommended by (Kock, 2015). Third, the researchers used the PLS marker variable approach to create a method factor as suggested by (Lindell & Whitney, 2001). Cognitive Rigidity was used as a marker variable which contains three items that were included in the survey but excluded from the tested model. These items are: (1) "Once I've come to a conclusion, I'm not likely to change my mind;" (2) "I don't change my mind easily;" and (3) "My views are very consistent over time" (Oreg, 2003). Then, this marker variable was used as an exogenous variable predicting all endogenous construct in the model. Next, the researchers compared the model containing the marker variable with the original model and found that the R^2 of all endogenous construct did not increase more than 10% of the variance as recommended by (Lindell & Whitney, 2001). Finally, Table 5 shows that the correlation between the constructs in the models is less than 0.9. Because of all these given data, CMV is no longer a concern in this study.

Table 5 HTMT results for discriminant validity

Constructs	BI	COMP	OB	ATT	PBC	PSR	RA	SN
BI								
COMP	0.828							
OB	0.825	0.829						
ATT	0.873	0.744	0.717					
PBC	0.640	0.651	0.767	0.41				
PSR	0.704	0.759	0.831	0.581	0.801			
RA	0.824	0.893	0.862	0.792	0.534	0.673		
SN	0.815	0.772	0.881	0.654	0.776	0.655	0.727	

Fig. 2 Measurement model

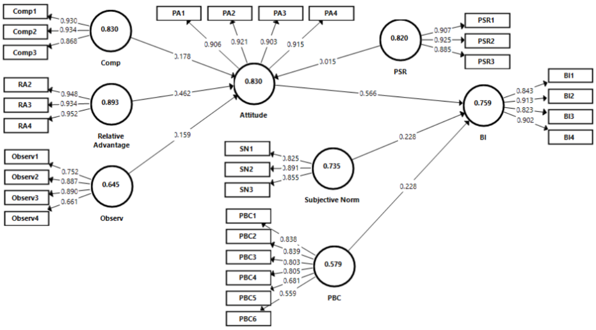

Table 6 Inner VIF for the predictors

Constructs	BI	ATT	PBC	SN
COMP		3.599	3.222	3.222
OB		3.165	2.602	2.602
ATT	1.581			
PBC	1.85			
PSR		2.311		
RA		3.837	3.816	3.816
SN	2.425			

Table 7 Hypotheses Testing and Effect Sizes

						BC-CI (95%)	
Hypo	Paths	Beta	T-value	P-value	Decision	LB	UB
H1	ATT -> BI	0.570	10.666	0.000	accepted	0.477	0.654
H2	SN -> BI	0.232	3.539	0.000	accepted	0.127	0.344
H3	PBC -> BI	0.220	4.084	0.000	accepted	0.134	0.312
H4	COMP -> ATT	0.178	1.592	0.056	rejected	-0.002	0.362
H5	RA -> ATT	0.491	5.388	0.000	accepted	0.329	0.631
H6	OB -> ATT	0.117	1.205	0.114	rejected	-0.027	0.300

4.3 Measurement model

Next, the researchers exerted a two-stage approach suggested by Anderson & Gerbing (1988) to test the model. In the first stage, they tested the measurement model and in the second stage, they tested the structural model as follows.

The measurement model is composed of some procedures to measure the psychometric properties of the variables. The first step is the estimation of the reliability of the constructs which is assessed using composite reliability. The second step is the estimation of the convergent validity which is measured using factor loadings and average variance extracted (AVE) of the constructs. The third step is to evaluate the discriminant validity of the constructs. The discriminant validity was tested using the HTMT criterion as it produces more precise results concerning discriminant validity (Henseler et al., 2015). Moreover, the cross-loadings criterion was used in this study for remedy purposes in the discriminant validity procedures.

Table 2 displays the results of the factor loadings and Table 3 shows the results of Cronbach's alpha and composite reliability and AVE for all constructs. Based on Hair, Risher, Sarstedt, and Ringle's (2019) criteria, all the constructs passed the threshold value for construct convergent validity because all the constructs gained AVE of more than 0.5 and the factor loadings are more than 0.708 for all items except for one item. Items with less than 0.708 can be kept in the model if the value of the AVE is more than 0.5 in that construct (Hair et al., 2019). Furthermore, composite reliability and Cronbach's alpha are higher than the cut-off value of 0.7 for all the constructs which indicate that the internal reliability of the constructs is high (Hair et al., 2019).

To test discriminant validity, the researchers employed HTMT criteria(Henseler et al., 2015). The results of the relative advantage construct are higher than the threshold (0.9). Therefore, item RA1 was deleted because it correlated highly with the Compatibility construct as cross-loading confirmed. After deleting the item, the value of the HTMT criteria is less than 0.9 as shown in Table 4. Therefore, the discriminant validity for all the constructs was established.

4.4 Structural model: hypotheses testing

The structural model assessment contains five steps. The first step is the multicollinearity, variance inflation factor (VIF) between all the endogenous constructs (Becker et al., 2015), which should be less than 5. The second part is testing the t-value and the p-value. The third step is to examine the Coefficient of Determination (R^2). The fourth assessment is the effect size (f^2) and the last one is the predictive power of the model (Geisser, 1975).

To start with, all the values of VIF of the predictor in the model are less than 5 which is considered appropriate for assessing the model and there is no multicollinearity issue in the model (Becker et al., 2015; Cassel et al., 1999). The researchers used the inner VIF scores because all the predictors are reflective, not formative. Table 5 shows the results of the inner VIF scores of the predictors in the model.

Furthermore, in this study, the researchers tested the hypotheses of the structural model by employing a bootstrapping sampling technique of 5000 iterations of a subsample which is suggested by Hair et al., (2016). Table 6 displays the findings of the structural model. The results indicate that perceived attitudes have a positive impact on behavioral intention of using virtual reality (H1: $\beta = 0.570$, $p < 0.001$), and SN affects behavioral intention toward virtual reality positively (H2: $\beta = 0.232$,

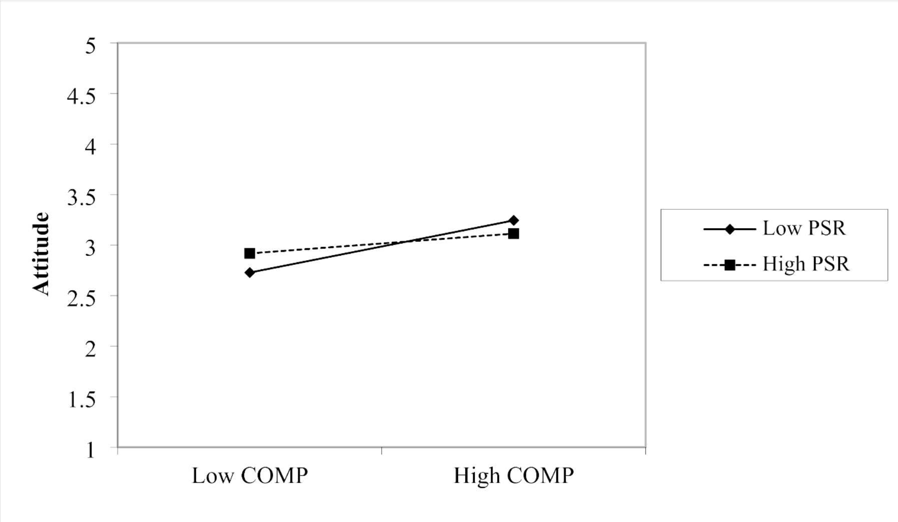

Fig. 3 PSR moderates OB and attitude

p<0.001). Next, Perceived Ease of Use affects behavioral intention when using virtual reality positively (H3: β=0.220, p<0.001). RA affects ATT towards using virtual reality positively (H5: β=0.491, p<0.001), however, no support was found of the influence of COMP on ATT (H4: β=0.178, p=0.056). Finally, it is maintained that Obser could not affect ATT (H6: β=0.117, p=0.114).

4.5 Moderating effect of perceived skills readiness

Besides, following Preacher & Hayes's (2004) bootstrapping approach as shown in Table 7, the results of moderation indicate that the positive relationship between perceived attitude and COMP (H7: β = -0.080, p=0.018), RA (H8: β = -0. 102, p=0. 007) and OB (H9: β = -0. 111, p=0. 007) was found to be significantly stronger when Perceived Skills Readiness is high as illustrated in Figs. 3, 4 and 5 respectively. This interaction plot is suggested by Dawson (2014).

Next, the researchers tested the coefficient of determination (R^2) to examine the in-sample predictive power. R^2 is calculated for the endogenous constructs and it is rendered weak, moderate and substantial if the value of the R^2 is 0.25, 0.50 and 0.75 respectively (Hair et al., 2016). As illustrated in Fig. 3, all the endogenous constructs have substantial power in the model. Specifically, the findings showed that 76% of the variance in BI is explained by ATT, SN and PBC, while only 57.4% of the variance in attitude is explained by COMP, RA and OB.(refer to Table 8).

Regarding the effect sizes (f^2), Cohen (1992) postulated that the effect size is considered small, medium and large if the values are over 0.02, 0.15 and 0.35 respectively. Thus, as displayed in Table 8, ATT (f^2=0.859) represents a large effect size on BI while PBC (f^2=0. 109) and SN (f^2=0.093) demonstrated a small effect size on BI. However, all three predictors (COMP, OB and RA) portrayed a small effect size in generating R^2 for ATT.

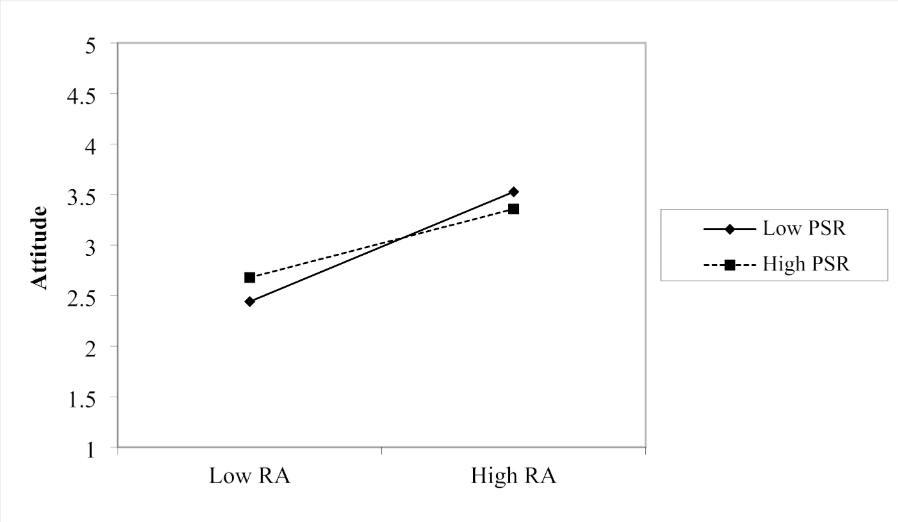

Fig. 4 PSR moderates RA and attitude

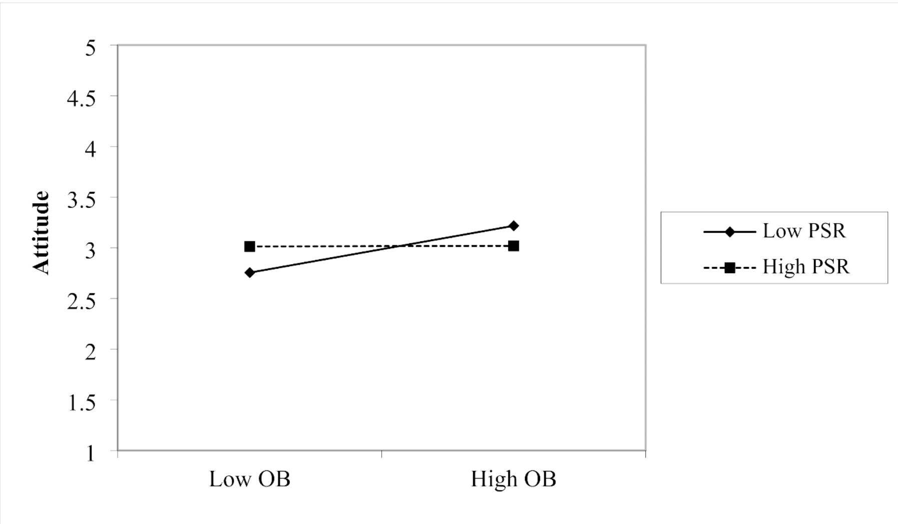

Fig. 5 PSR moderates OB and attitude

Table 8 Moderating effects of perceived skills readiness

						BC-CI (95%)		f^2
Hypo	Paths	Beta	T-Vaue	P-value	Decision	LB	UB	
H7	COMP*PSR -> ATT	-0.080	2.102	0.018	accepted	-0.143	-0.021	0.023
H8	RA*PSR -> ATT	-0.100	2.479	0.007	accepted	-0.172	-0.039	0.031
H9	OB*PSR -> ATT	-0.114	2.474	0.007	accepted	-0.190	-0.044	0.045

Table 9 R square, Effect Sizes and Q square

		Effect size (f^2)				
	R square	BI	ATT	PBC	SN	Q square
COMP			0.021	0.102	0.071	
OB			0.010	0.215	0.226	
ATT	0.574	0.859				0.457
PBC		0.109				
RA			0.147	0.02	0.002	
SN		0.093				
BI	0.760					0.568

Table 10 Assessment of PLSPredict

	PLS		LM		PLS-LM		
Items	RMSE	Q²_predict	RMSE	Q²_predict	RMSE	Q²_predict	Predictive Power
BI2	1.157	0.480	1.212	0.430	**-0.055**	**0.050**	**High**
BI4	1.008	0.601	1.054	0.563	**-0.046**	**0.038**	
BI1	1.266	0.413	1.281	0.399	**-0.015**	**0.014**	
BI3	1.431	0.418	1.522	0.342	**-0.091**	**0.076**	
PA1	0.856	0.422	0.901	0.358	**-0.045**	**0.064**	**Meduim**
PA4	0.772	0.490	0.831	0.410	**-0.059**	**0.080**	
PA2	0.750	0.409	0.807	0.316	**-0.057**	**0.093**	
PA3	0.792	0.478	0.775	0.500	**0.017**	**-0.022**	

Regarding the predictive power of the model, the researchers first used the blindfolding technique recommended by Geisser (1975). It was found that the proposed model has a predictive power because the Q^2 of all the endogenous constructs is greater than 0 (Geisser, 1975; Stone, 1977) as shown in Table 7.

4.6 PLS-Prediction

PLSPredict is one of the most recent out-of-sample technique that is suggested by Shmueli et al., (2019) and Hair et al., (2017) in SmartPLS 3.3.5. It generates a holdout sample to be compared with the original sample. Table 8 shows the results of the PLSPredict procedures. RMSE is considered the main criteria for the assessment of prediction in the recent study which can be used to compare the PLS model and the linear model. The results indicated that behavioral intention has high prediction power in the model whereas attitude holds medium predictive power. Moreover, Q^2-predict values indicate that the PLS model outperforms the linear model because most of the Q^2-predict values are greater than 0. Thus, we can conclude that the framework model in the current study has strong predictability,

5 Discussion

5.1 Theoretical contribution

The past few years have witnessed a notable growth of studies that investigated the factors affecting emerging technologies among teachers at schools. Recent studies highlight the need to progress our understanding of the factors that influence employing virtual reality and augmented reality while teaching science. To this end, this study works in this direction. This study could be considered novel as it integrates two well-known theories, TPB and IDT in one model. The assessment of the results emphasized the proposed relationships between the TPB constructs and the behavioral intention of using virtual reality. However, no support was found in the relationship between COMP and OB constructs (IDT constructs) and attitude towards virtual reality except for relative advantage. Moreover, it is found that perceived skills readiness can strengthen the relationship between COMP, RA and OB and attitude towards virtual reality usage.

5.2 Implications

Firstly, all three constructs predicted behavioral intention of using virtual reality in teaching science significantly with attitude as the strongest predictor followed by social norms then perceived behavioral control. This result is in line with Puah, Bin Mohmad Khalid, Looi, & Khor's study (2021) where they used the decomposed theory of planned behavior to predict adults' use of microlearning. This result implies that science teachers must develop a positive attitude towards employing virtual reality while teaching more than focusing on social influence or teachers' control over virtual reality applications. To promote a strong attitude towards using virtual reality among science teachers, three predictors were investigated in the model. The relative advantage was the significant predictor with a stronger effect size while compatibility and observability were not significant predictors at all. This result is inconsistent with that of Santos & Okazaki (2013) in which the researchers examined the e-learning adoption among Brazilian faculty members. These results entail that it is recommended to promote the benefits of virtual reality over the conventional methods of teaching so that teachers can adopt this kind of strategy. However, there is no need to improve the congruency of using virtual reality nor the virtual reality must be visible in the school so that science teachers hold a better attitude toward using it.

Additionally, perceived skills readiness was found to significantly moderate compatibility, relative advantage and observability and attitude toward using virtual reality. Thus, when virtual reality proliferates among science teachers, those who are ready to use technology efficiently, would be able to use virtual reality in the classroom easily. In fact, perceived skills readiness can offer a facilitating condition that allows science teachers to obtain a positive attitude and hence adopt virtual reality in their teaching.

6 Conclusion, limitations and directions for future research

Based on TPB and DIT, the proposed model confirmed the relationship between the TPB constructs, namely, ATT, SN and PBC and the intention to use virtual reality application in the science classrooms in Oman. In addition, one of the teachers' beliefs about the characteristics of virtual reality application namely, relative advantage, is a strong factor for predicting attitude towards virtual reality usage but COMP and OB do not have any effect on attitude. The results also confirmed the moderating role of perceived skills readiness between the characteristics of virtual reality application and attitude towards virtual reality usage. Thus, in order to leverage the usage of virtual reality by the science teachers, schools' headmasters, policymakers should find ways to promote teachers' attitudes and support them extensively to become ready for using this type of technology in the future. By doing this, teachers will have a positive attitude towards virtual reality usage so that they will use it confidently. Although this study contributes to the existing literature on virtual reality usage, it is not without some limitations. First, as this study is aimed at science teachers only, future research can be conducted on other subjects such as English, maths and social studies to mention a few. Second, the confirmed use of perceived skills readiness as a moderating variable in this study opened a discussion of integrating this variable in other types of inconsistent relationships such as the relationship between the intention to use and actual intention. Finally, the proposed model in this study considers only science teachers in Oman. As science teachers around the world may share the same attributes, it can be said that our results can be transferable to other parts of the world if they have common attributes as shown in the sample characteristics table in Sect. 3.2.1. However, this was conducted in Oman, thus, future research could examine the adoption of virtual reality in other countries around the world and may also focus on cross-cultural comparisons such as comparing between the western and eastern countries regarding using virtual reality by science teachers.

7 Appendix

Variable	Description of items	Adapted from
Perceived Attitude	PA1: I like the idea of using virtual reality in my teaching.	Long & Khoi (2020)
	PA2: Continuing to use virtual reality in my teaching is a good idea.	Long & Khoi (2020)
	PA3: I agree with the continued use of virtual reality in teaching science.	Long & Khoi (2020)
	PA4: I am satisfied with my intention to continue using virtual reality in teaching science.	Long & Khoi (2020)
Behavioural Intention	BI1: I am interested to use virtual reality in teaching science.	Waheed et al., (2015)
	BI2: I intend to use virtual reality in teaching science.	Waheed et al., (2015)
	BI3: I prefer to use virtual reality in teaching science rather than traditional laboratory.	Waheed et al., (2015)

Variable	Description of items	Adapted from
	BI4: I intend to use virtual reality in teaching science regularly in future.	Waheed et al., (2015)
Subjective Norms	SN1: My science supervisors think that I should use virtual reality in my teaching.	Bervell & Arkorful (2020)
	SN2: My science senior teachers would prefer that I adopt virtual reality in my teaching.	Bervell & Arkorful (2020)
	SN3: If I use virtual reality, my science colleagues would also use it.	Bervell & Arkorful (2020)
Perceived Behav-ioural Control	PBC1: I can easily use virtual reality when needed.	Shih & Fang (2004)
	PBC2: I would be able to use virtual reality in my teaching.	Shih & Fang (2004)
	PBC3: I have the resources to use virtual reality in my teaching.	Shih & Fang (2004)
	PBC4: I have the knowledge to use virtual reality in my teaching.	Shih & Fang (2004)
	PBC5: There is sufficient guidance/support from my school on how to teach using virtual reality.	Lee & Kang (2013)
	PBC6: There is a budget allocated for implementing virtual reality in my school.	Lee & Kang (2013)
Compatibility	COM1: Virtual reality fits well with the way I like to teach my lessons.	Al-Jabri & Sohail (2012)
	COM2: Virtual reality is compatible with my teaching style.	Al-Jabri & Sohail (2012)
	COM3: Using virtual reality fits into the science curriculum.	Al-Jabri & Sohail (2012)
Relative Advantage	RA1: Virtual reality would have a positive impact in my school.	Kaufman et al., (2021)
	RA2: I can see the differences that virtual reality implementa-tion brings.	Lee & Kang (2013)
	RA3: Using teaching-related virtual reality activities is beneficial.	Kim et al., (2020)
	RA4: I can see the effect of using virtual reality on raising student motivation immediately.	Al-Jabri & Sohail (2012)
Observability	OB1: Virtual reality is visible around my school.	Wang et al., (2021)
	OB2: It is expected that my students will show interest in virtual reality apps when they see me using them	Atkinson (2007)
	OB3: If I use virtual reality, then others will know that I am doing so.	Wang et al., (2021)
	OB4: I am more likely to use virtual reality because my col-leagues employ it in their teaching.	Wang et al., (2021)
Perceived Skill Readiness	PSK1: I have the skills I would need to teach using virtual reality	Al-Maroof et al., (2021)
	PSK2: I can use virtual reality applications to include activi-ties for my lessons.	Al-Maroof et al., (2021)
	PSK3: I can use websites (e.g. PhET Crocodile, Mag Lab, etc.) to access information/services related to virtual reality usage.	Al-Maroof et al., (2021)

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

Declaration

Conflict of interest The authors declare no conflicts of interest.

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