Contemporary Educational Technology, 2023, **15**(2), ep407
ISSN: 1309-517X (Online)

OPEN ACCESS

Research Article

The effects of TPACK and facility condition on preservice teachers' acceptance of virtual reality in science education course

M. Anas Thohir [1*]
0000-0002-4865-253X

Erif Ahdhianto [1]
0000-0003-2354-7079

Siti Mas'ula [1]
0000-0001-8059-626X

Fitri April Yanti [2]
0000-0003-1169-8806

Moh Irma Sukarelawan [3]
0000-0002-3823-3964

[1] Department of Elementary and Preschool Education, Universitas Negeri Malang, Malang, INDONESIA
[2] Faculty of Education, Universitas Bengkulu, Bengkulu, INDONESIA
[3] Department of Physics Education, Universitas Ahmad Dahlan, Yogyakarta, INDONESIA
[*] Corresponding author: anas.thohir.fip@um.ac.id

Citation: Thohir, M. A., Ahdhianto, E., Mas'ula, S., April Yanti, F., & Sukarelawan, M. I. (2023). The effects of TPACK and facility condition on preservice teachers' acceptance of virtual reality in science education course. *Contemporary Educational Technology, 15*(2), ep407. https://doi.org/10.30935/cedtech/12918

ARTICLE INFO

Received: 5 Nov 2022
Accepted: 3 Jan 2023

ABSTRACT

Virtual reality (VR) is developing in line with the establishment of the learning metaverse, although the relationship between its acceptance and technological pedagogical content knowledge (TPACK) is very unclear. Therefore, this study aims to determine the effects of facility condition (FC), technological acceptance model (TAM), and TPACK on pre-service teachers' use of VR in Indonesian science education courses. This condition emphasizes the description of these teachers' readiness in designing VR for learning and teaching integration. The survey was conducted using 406 preservice teachers from 12 Indonesian universities, with confirmatory factor analysis (CFA) and partial least square-structural equation model (PLS-SEM) subsequently utilized. The results showed that PU (perceived usefulness), PEOU (perceived ease of use), behavior Intention (BI), TPACK, and FC were significantly and positively related. However, two hypotheses emphasizing the relationship between FC and TPACK to PEOU were rejected. These results are expected to facilitate preservice teachers in easily adopting VR learning in courses.

Keywords: virtual reality, TPACK, TAM, PLS-SEM, pre-service teacher

INTRODUCTION

Virtual reality (VR) is rapidly developing as a future interactive medium with various advantages in the educational field (Fussell & Truong, 2021; Tsivitanidou et al., 2021). Aligning with the organizational change of Facebook to Meta regarding its investment in Metaverse (Kraus et al., 2022), VR is reportedly becoming more popular in integrating classroom learning. This is a consequence of the metaverse as a fully or partially virtual medium, including systems in VR or augmented reality (AR) (Hwang & Chien, 2022). The medium also provides realistic 3D experiences (Xiong et al., 2021), real-time activities (Mahalil et al., 2020), and social communication (Hwang & Chien, 2022). Moreover, VR influences self-efficacy, knowledge (Meyer et al., 2019), motivation,

increased learning outcomes, and cognitive processes (Kemp et al., 2022). These advantages show that prospective teachers need to determine and understand the patterns by which the medium is used for learning. The challenge also supports readiness with teacher candidates' acceptance of new technologies (Kaushik & Agrawal, 2021; Lin et al., 2007). This allows them to adapt by integrating VR into inquiry-supported learning. Irrespective of these merits, an encountered challenge still emphasizes the patterns by which this technology is accepted by prospective teachers in designing future learning.

Technology acceptance model (TAM) has become a popular measuring tool for modelling human acceptance or rejection of new technologies (Barrera-Algarín et al., 2021; Granić & Marangunić, 2019). The extraordinary work of this model was introduced by Davis (1989), where usefulness-usage and ease-of-use had a strong relationship. This explained that designers should identify friendly users and the usefulness of new technology, toward goal achievement (Davis et al., 1989). According to Granić and Marangunić (2019), teachers' acceptance of more specific technologies such as VR, should be explored. The exploration of preservice teachers' acceptance of VR was also carried out by several previous reports, such as Altarteer and Charissis (2019), Fussell and Truong (2021b, p. 1), Jang et al. (2021a), and Lee et al. (2019). For example, Fussell and Truong (2021) provided some external variables such as expectation, self-efficacy, and enjoyment, to students' acceptance of VR in training. Kemp et al. (2022) also emphasized acceptance regarding cognitive involvement, social influence, system attributes, and facility conditions (FCs). However, how will preservice teacher acceptance of VR adoption be adapted to future learning contexts? Technology integration also requires adequate facilities, such as hardware and software infrastructure. Therefore, the integration of VR into learning is unstructured when it is transformed into content learning accordingly.

Irrespective of these results, a few external factors of VR-TAM were prioritized concerning pre-service teachers as designers (Alalwan et al., 2020; Jang et al., 2021). To describe the acceptance of appropriate technology, TAM is capable of influencing the curriculum and assessment of digital competencies, teacher virtual adoption, and technological external variables (Scherer et al., 2019). In this case, teachers should specifically accept TAM to integrate VR into learning (Jang et al., 2021). This subsequently leads to the utilization of technological pedagogical content knowledge (TPACK), which is a concept often used to measure preservice teachers' integration of digital learning technology (Schmid et al., 2021; Thohir et al., 2021; Valtonen et al., 2019). This framework has reportedly been cited for more than 14000 works since its proposal by Mishra and Koehler (2006). Therefore, this study aims to determine the effects of FC, TAM, and TPACK on preservice teachers' use of VR in Indonesian science education courses. This condition emphasizes the description of these teachers' readiness in designing VR for learning and teaching integration.

THEORETICAL REVIEW

Virtual Reality

VR is not a new technology due to its long-term existence since 1994, where its definition emphasized "anywhere a user is effectively immersed in a responsive digital world" (Brooks, 1999). Based on previous reports, VR was originally implemented as a flight training simulator with large and expensive equipment (Page, 2000). In this context, the Simulator was considered the first immersive VR capable of combining display, sound, and motion (Araiza-Alba et al., 2022). This provided an immersive and interactive real environment and digital world experience (Sukotjo et al., 2021). It was also carried out using 3D goggles and data gloves, leading to its consideration as second life (Rospigliosi, 2022). Therefore, VR reportedly improves students' cognitive development, procedures, and affective domains, especially in science learning (Hamilton et al., 2021; Liu et al., 2020; Parong & Mayer, 2018, 2021).

VR has also become the future spatial immersive technology with a new paradigm known as Metaverse (Han et al., 2022; Mystakidis, 2022). Irrespective of the merits, this technology is still developing in educational, social, and working fields (Rospigliosi, 2022; Xi et al., 2022). According to a review, its development had reached the characteristics of learning styles, animations, narrative, and social integration (Matovu et al., 2022). Furthermore, various types of VR are being continuously developed, such as desktop (DVR), mobile (MVR), cave automatic virtual environments (CAVE), immersive (IVR), AR systems (Araiza-Alba et al., 2022), and XR (extended reality) (Doolani et al., 2020). Some usable recommendations also emphasize new head-

mounted displays (HMDs) such as the oculus rift and HTC Vive (Grassini & Laumann, 2020). Irrespective of these conditions, this technology is still not ready to be used evenly, due to its relatively expensive equipment and development (Hernández-de-Menéndez et al., 2019; Laurell et al., 2019; Perret & Vander Poorten, 2018).

Technology Acceptance Model and Facilities Condition

TAM is one of the psychological theories of human behavior, which is widely applied and empirically tested to show people's acceptance of ICT (Rahimi et al., 2018). Based on some reports, this model was used to predict the integration patterns of technology (Joo et al., 2018; Scherer et al., 2019; Sukendro et al., 2020). It was also initially proposed by Davis (1985), regarding its development from the theory of reasoned action (TRA), which contained three variables, namely behavioral intention (BI), attitude (AT), and subjective norm (SN) (Davis et al., 1989). Firstly, BI focuses on a person's intensity in performing a specific activity. Secondly, attitude is a person's positivity towards the target behavior. Thirdly, SN is the perception of an individual or most people, which motivates expected and unexpected performance. In this case, the SN variable was replaced with PU (perceived usefulness) and PEOU (perceived ease of use) (PEOU), which have a strong relationship with BI. According to Davis (1989), PEOU was also affected by PU. In addition, AT has reportedly been dispensed for more complex analysis in other studies (Venkatesh & Davis, 2000), although some retained SN and AT (Alshurafat et al., 2021; Ibili et al., 2019; To & Tang, 2019). For this present report, essential TAM is emphasized, regarding the exploration among PU, PEOU, and BI, as well as the provision of external variables (Fagan et al., 2012; Jang et al., 2021a; Kemp et al., 2022b). This leads to the proposition of the following hypotheses,

1. **H1:** PU significantly affects BI.
2. **H2:** PEOU significantly affects BI.
3. **H3:** PEOU significantly affects PU.

TAM is an emerging model used to examine teachers' acceptance of new technology and external variables (Eraslan Yalcin & Kutlu, 2019; Hsu & Lu, 2004; Mailizar et al., 2021). From this context, over 7000 citations of original articles (Davis, 1989) searches are obtained from Google Scholar, with more reports retaining original works than modified TAM (Granić & Marangunić, 2019). Some studies also evaluated the acceptance of VR as a technology requiring learning application (Fagan et al., 2012; Fussell & Truong, 2021; Jang et al., 2021; Kemp et al., 2022; Manis & Choi, 2012). 2019; Sagnier et al., 2020; Vallade et al., 2021). However, other reports regarding the acceptance of preservice teachers on the adoption of VR as a learning technology are limited. According to Jang et al. (2021), the relationship between the utilization of TPACK to TAM was identified due to the different conditions of VR adoption in various countries. The external variable is also an important component to be explored, for example, disability conditions (Ranellucci et al., 2020), immersion, imagination (Barrett et al., 2020), presence, experience value, and object costuming (Altarteer & Charissis, 2019). Among the various external TAM variables, the conditional factor needs to be considered toward the adjustment of technology adoption readiness (Kamal et al., 2020; Pal & Vanijja, 2020; Salloum et al., 2019; Sukendro et al., 2020).

FC is often included as an important external variable, to indicate extended TAM (Beldad & Hegner, 2018; Kamal et al., 2020; Natasia et al., 2022; Sukendro et al., 2020). This is specifically an important variable for the acceptance of technology, through PU and PEOU. According to Sukendro et al. (2020), FC was part of the appropriate, usable, and easy facilities whose environment was good. However, several studies only emphasized the significance between FC and PU (Natasia et al., 2022). These conditions lead to the proposition of the following hypotheses,

4. **H4:** FC significantly affects PU.
5. **H5:** FC significantly affects PEOU.

Virtual Reality-Technological Pedagogical Content Knowledge

As future educators, preservice teachers need to have technological, pedagogical, and content knowledge (TK, PK, and CK) competencies, which were proposed by Mishra and Koehler (2006) and integrated into TPACK. This concept was developed from the pedagogical content knowledge (PCK) of Shulman (1987), which subsequently produced additional frameworks, namely TCK (technological content knowledge) and TPK

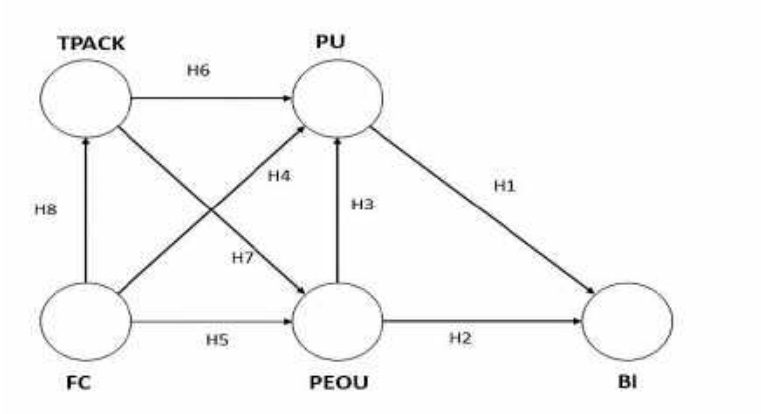

Figure 1. Hypothetical model (Source: Authors' own elaboration)

(technological pedagogical knowledge). TPACK is also commonly used to adopt or design the planning and implementation of learning technology (Dong et al., 2020; Murgu, 2021; Ozgur, 2020; Thohir et al., 2022). This enables the patterns by which VR is adopted through the pedagogical and content concepts, according to the learning context. For example, Marks and Thomas (2022) explored students' VR design for laboratory learning. The VR acceptance of preservice teachers also prioritizes the integration of this technology into the lesson plan and implementation (Eutsler & Long, 2022; Farrell et al., 2022).

Irrespective of these descriptions, an encountered challenge focused on the patterns by which TAM associates with preservice teachers' TPACK, toward VR learning adoption. In this context, some previous studies showed that TPACK was associated with PU and PEOU, although only a few were observed (Jang et al., 2021a; Yang et al., 2021). Furthermore, prospective teachers adopted the integration of VR acceptance into strong learning. This describes that different contexts enabled the performance of VR learning adoption through various acceptance outcomes. Regarding these results, the difficulty in designing VR affected usage acceptability or ease of acceptance. This mitigates the patterns by which VR is integrated into planning, implementation, and evaluation (Hayes et al., 2021). The conditions for designing this technology also require high-recommendation facilities, such as 3D and game software applications (Solmaz & Van Gerven, 2022). This confirms the existence of an influence on the facilities and TPACK. Based on this theory, the following hypotheses are proposed,

6. **H6:** TPACK significantly affects PU.
7. **H7:** TPACK significantly affects PEOU.
8. **H8:** FC significantly affects TPACK.

METHOD

Procedure and Participants

Based on **Figure 1**, this analysis was conducted by distributing an online survey through a google form, to specifically identify individual beliefs and attitudes (Creswell, 2020). This data collection process lasted for 28 weeks, through the acquisition of permission from the university lecturers to distribute the survey.

Table 1 shows the demographics of the participants selected from department of elementary school teacher education in 12 Indonesian universities, between semesters 1-7. There were 406 participants who were invited to fill out the survey with details, 14.3% (n=58) were male and 85.7% (n=348) were female. They have been taking educational technology courses for science for elementary school. For example, prospective teachers have taken technology development courses in first semester. They have been introduced to VR with the eventual goal of adopting it in the next semester's lesson plan, especially science content. The table also shows that 74.6% (n=303) prospective teachers knew about VR before the course, while the rest did not. This represents that the majority of preservice teachers already have knowledge about VR in the metaverse. Then, most of these preservice teachers were laymen in using VR, leading to the identification of the novices yet to design and implement the technology.

Table 1. Descriptive of participants in the VR acceptance survey

Components	n	Minimum	Maximum	Mean	Standard deviation
Age	406	17	25	19.64	1.35
Semester	406	1	7	4	1.89
Gender			Male=58 (14.3%) Female=348 (85.7%)		
VR knowledge			Knowing VR=303 (74.6%) Not knowing VR=103 (25.4%)		

Table 2. Descriptive statistics of TPACK, FC, and TAM

Factor	n	Mean	Standard deviation
TPACK	406	3.72	.65
FC	406	3.37	.72
PU	406	4.10	.69
PEOU	406	3.92	.61
BI	406	3.91	.69

Note: TPACK: Technological pedagogical content knowledge; FC: Facility condition of VR design; PU: Perceived usefulness; PEOU: Perceived ease of use; & BI: Behavior intention

Instrument

An instrument designed with the following two important parts was used:

1. The demographics describing the participants' characteristics and VR knowledge. This includes the email, gender, age, university origin, and VR knowledge of the participants.
2. The variables of VR and TPACK acceptance obtained from the literature review. This includes PU (five items), PEOU (five items), BI (four items), TPACK (four items), and FC (four items).

The items statement was also modified from multiple literature reviews (Davis, 1989; Fussell & Truong, 2021; Jang et al., 2021; Park, 2009). Besides being modified from the original Davis (1989) TAM, the questionnaires of PU and PEOU were also developed from other reports (Granić & Marangunić, 2019; Jang et al., 2021). These were accompanied by the instruments of BI, TPACK, and FC, which were developed by Davis (1989), Fussell and Truong (2021), and Park (2009), Schmidt et al. (2009), and Jang et al. (2021), as well as Kemp et al. (2022) and Park (2009), respectively. Moreover, each item had a response scale of 1 (strongly disagree) to 5 (strongly agree). This instrument was subsequently consulted with four lecturers and three pre-service teachers, to validate the content and language. Several revisions were also observed, such as the replacement of appropriate sentences, inappropriate instructions, and typographical errors. After these replacements, the survey instrument was then distributed to obtain data, with the validation and reliability of the results empirically derived. For completeness, the instrument is attached to **Appendix A** in the translated version.

Data Analysis

This was conducted to determine the validity, reliability, structural, and model fit. In this process, EFA (exploratory factor analysis) and CFA (confirmatory factor analysis) were initially used to explore possible variables, as well as determine the number of factors and items obtained regarding an LF (loading factor) of more than 0.5 (Beauducel & Herzberg, 2006). Using SPSS 25 software from IBM, these experimental methods were subsequently analyzed. Cronbach's alpha, and correlation between variables were also calculated using this software. In addition, the data obtained were analyzed using SmartPLS 4 and PLS-SEM, to determine the most appropriate structural fit model, such as standardized root mean square residual (SRMR) and NFI (normed fit index).

RESULTS

Descriptive Data

Based on the results, the acceptance of preservice teachers in integrating VR into learning provided an average value greater than three, as shown in **Table 2**. This indicates that PU (M=4.10, SD=.69) and FC (M=3.37, SD=.72) had the highest and lowest average scores, respectively.

Table 3. Loading factor and reliability of TPACK, FC, and TAM components

Items	BI	FC	PEOU	PU	TPACK	Cronbach's alpha	Composite reliability	AVE
BI1	.92					.91	.91	.78
BI2	.92							
BI3	.89							
BI4	.81							
FC1		.80				.82	.86	.65
FC2		.86						
FC3		.76						
FC4		.79						
PEOU1			.83			.89	.90	.71
PEOU3			.87					
PEOU4			.83					
PEOU5			.84					
PU1				.91		.95	.95	.83
PU2				.91				
PU3				.90				
PU4				.92				
PU5				.92				
TPACK1					.84	.87	.87	.73
TPACK2					.86			
TPACK3					.87			
TPACK4					.83			

Table 4. Correlation between VR acceptance items with TPACK and Fornell-Larcker criterion

	BI	FC	PEOU	PU	TPACK
BI	**.89**				
FC	.43**	**.80**			
PEOU	.76**	.45**	**.84**		
PU	.77**	.32**	.78**	**.91**	
TPACK	.51**	.55**	.54**	.50**	**.85**

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

TPACK (M=3.70, SD=.65) was also observed with the second lowest value after FC. This proved that a relationship was found between infrastructure and knowledge of VR adaptation in learning activities.

Validity and Reliability

Using the EFA principal components rotation method, the data obtained were explored to obtain the preservice teachers' acceptance factor for VR, regarding the eigenvalues greater than one. Bartlett sphericity test also showed a value of .92, with 2/df=16.92 and p=.000. This means that the variances were equal between the samples, indicating a cumulative value of 70.73%. However, only four components were observed with AT and PU in one factor. From these results, CFA was applied by establishing six possible factors through the elimination of AT, regarding previous studies. In this case, the loading factor was greater than .6, with the total shown in **Table 3**. For construct reliability, all items were subsequently tested using Cronbach's alpha, CR (composite reliability), and average variance extracted (AVE), as presented in **Table 3**. For example, the table also presents all values of components reached over .8, fairly high reliability (Taber, 2018).

Table 4 shows the correlation of TPACK and the acceptance component of VR technology, indicating all variables were significantly and positively associated with values greater than r=.3. The strongest relationship was also observed between PU and AT (r=.85, p=.001), with the lowest association found between FC & PU (r=.33, p=0.001) and FC & AT (r=.33, p=.001). This confirmed that the perceived usefulness of teachers towards VR was closely related to positive attitudes. Based on the results, FC was slightly associated with the usefulness and positive attitudes of VR. This was due to the lack of facilities for designing VR, indicating no relationship between the benefits and uses. In addition, determination validation was carried out to determine the different types of factors. This was carried out by squaring the root of AVE against the other correlation criteria (Fornell & Larcker, 1981). For example, PEOU had a higher AV root value (0.84) than its correlation with BI (r=.76, p=.001), FC (r=.45, p=.001), PU (r=.78, p=.001), and TPACK (r=.54, p=.001). This showed that each TPACK component with TAM was significantly realized.

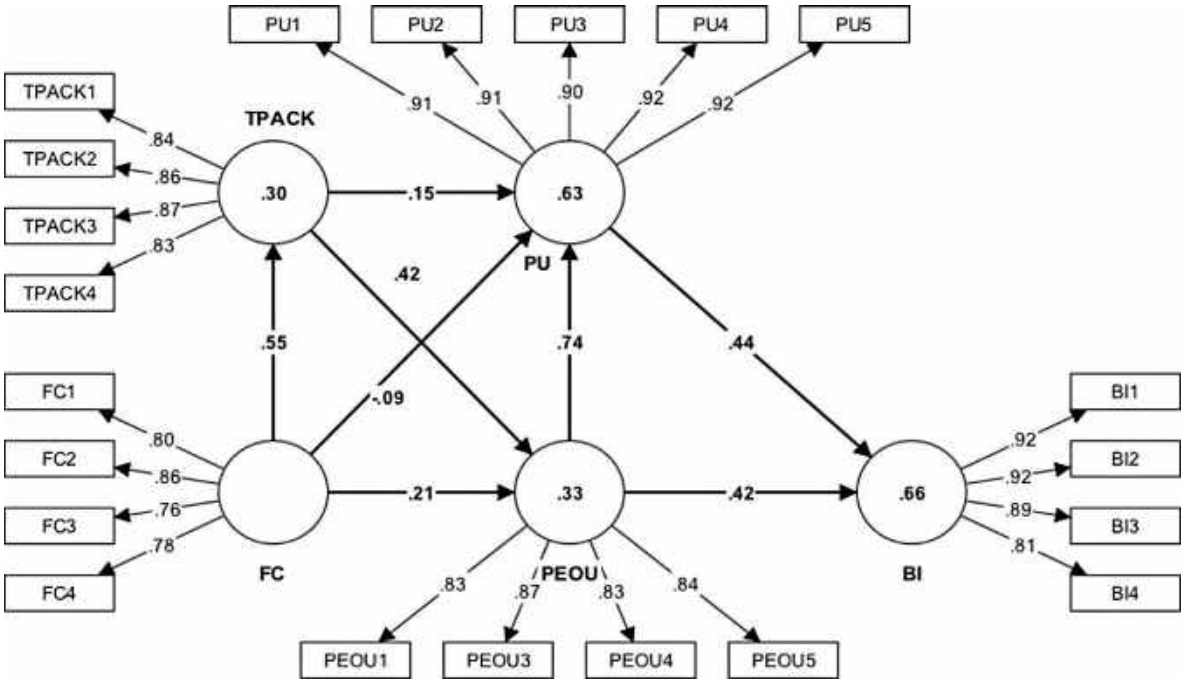

Figure 2. SEM VR acceptance of prospective teachers & its relationship with TPACK & FC (Source: Authors' own elaboration)

Structural Equation Model

Using smart PLS software, SEM was carried out to determine the impact of VR-TPACK on the acceptance of VR usage, as shown in **Figure 2**. The fit model of this test was also obtained from the SRMR at 0.06, indicating a value below the required average (0.06<0.08) (Hu & Bentler, 1998). Moreover, the NFI obtained a value of 0.9, which was close to one. **Figure 2** also shows R-squared measures (R2) as a regression coefficient (RC), which exhibits the contribution to the latent variable. For example, the BI variable had an RC of 66%, which was contributed by PU and PEOU.

Based on this correlation, mapping was carried out for the need for VR integration into pre-service teacher admissions. Using PLS-SEM, the analytical results showed the relationship between TPACK, facility support, and VR acceptance as a learning technology. From **Figure 2** and **Table 5**, careful identification of the model yielded the following important outcomes,

- **H1**, **H2**, **H3**, **H5**, **H6**, **H7**, and **H8** were accepted, except for **H4**. This indicates that the adoption of VR and facilities was related to VR ease of use in science learning. However, the facilities condition is not related to the acceptance of VR usefulness.
- The TAM-VR relationship was expressed as a TAM-extended development.
- The strongest relationship was PEOU->PU (β=.74) and FC->TPACK (β=.55). This was because the relationship between PEOU and PU influenced VR acceptance, due to the technology's ease of use. For FC and TPACK, strong relationship indicates that FC encouraged prospective teachers' VR adaptability.

DISCUSSION

This study aimed to determine the relationship between the prospective teachers' VR adoption, through TPACK and its acceptance. Based on the results, the survey instrument was valid and reliable to measure the relationship between TPACK and TAM. This was however the modification of several previous reports (Davis, 1989a; Fussell & Truong, 2021b; Jang et al., 2021a; Park, 2009), with the statement items adjusted for the acceptance of VR and VR-TPACK. Changes were also conducted to the context and characteristics of FCs and preservice teachers, respectively. This led to its utilization in determining the readiness of VR adoption before implementation (Iqbal & Ahmed Bhatti, 2015; Lin et al., 2007). In general, the identification of important

Table 5. Relationship between TPACK, FC, and technology acceptance model

Hypothesis	Path	β	t	p-value	f^2	Decision
H1	PU->BI	.44	7.49	.00	.22	Accepted
H2	PEOU->BI	.42	25.07	.00	.20	Accepted
H3	PEOU->PU	.74	19.39	.00	.97	Accepted
H4	FC->PU	-.09	7.95	.05	.01	Rejected
H5	FC->PEOU	.21	8.20	.00	.05	Accepted
H6	TPACK->PU	.15	5.49	.00	.02	Accepted
H7	TPACK->PEOU	.42	5.14	.00	.19	Accepted
H8	FC->TPACK	.55	12.31	.00	.43	Accepted

components of VR acceptance and adoption factors will lead to the readiness of prospective teachers to be able to perform in affordable technology integration.

The results also showed a relationship between the acceptance of VR and TPACK. Furthermore, most hypotheses represents a significantly positive relationship between TAM and TPACK, proving that **H1** (PU->BI), **H2** (PEOU->BI), and **H3** (PEOU->PU) had significant effects. This was in line with Davis (1989), which emphasized the acceptance of VR in preservice teachers (Legris et al., 2003; Yang & Wang, 2019). Irrespective of this condition, several reports still maintained their perceptions about SN and AT (Alshurafat et al., 2021; Ibili et al., 2019; To & Tang, 2019). From these findings, the preservice teachers perceived that technology adoption needs to consider the perceived usefulness and ease of using VR. In this case, POEU is likely to possess precedence over PU, to integrate VR into learning and teaching. This was in line with Jang et al. (2021), where TPACK affected TAM, regarding the PEOU of multimedia applications. However, Mayer & Girwidz (2019) greatly emphasized PU in the relationship between TPACK and TAM, indicating the need for subsequent future exploration. The findings imply that the instructor should also make sure to provide motivation on the utility of VR adoption, and how to novice preserve teachers can easily adopt VR in science learning courses.

FCs also significantly and positively influenced PEOU and TPACK, although not PU. This indicates that the ease of use of VR was affected by supporting various facilities, such as 3D modelling applications, game engines, and HMD (Safikhani et al., 2022; Sukendro et al., 2020). However, prospective teachers likely assumed that these tools did not impact the VR usability of VR (Gurer, 2021). These results were not in line with Natasia et al. (2022), where the FC->PEOU and FC->PU hypotheses were accepted and rejected in e-learning applications, respectively. The prospective teachers also perceived that design facilities affected the integration of VR into learning. This allowed VR to become a technology developing with the number and ease of learning design. The development of a strategy was also recommended for VR integration, using easy stages and supporting facilities. VR design templates might be used by implementing TPACK for affordable outcomes.

Several limitations on the survey participants and methods were also observed irrespective of the results obtained. Firstly, only the pre-service teachers from various Indonesian universities were selected for this study. This shows that subsequent future analysis should involve the participants from various countries, for broader and more formidable results. It should also be carried out at an international university, to facilitate identification of participants. Secondly, a quarter of the participants were not familiar with VR. Although an introductory video was provided on this technology, these teachers were still observed as novice users. From this context, the involvement of participants in VR training/course design is highly recommended. The PLS-SEM method should also be compared with CB-SEM, using AMOS, Lisrel, or MPlus software. In addition, a qualitative analysis should be considered an alternative in subsequent future reports, through interviews, observations, and documental evaluation of the prospective teachers designing VR.

CONCLUSION

The relationship between TPACK, TAM, and FC was assessed regarding the Indonesian preservice teachers' utilization of VR. This proved that the acceptance of VR was in line with Davis (1989), where a significant positive relationship was observed between PU, PEOU, and BI. Based on the results, TPACK also affected PEOU. Another contribution was the relationship between FC and TPACK/PEOU. These results had various

implications for instructors, regarding the integration of VR in learning, using easy strategies. Subsequent future report also need to apply this relationship for exploration through different perspectives.

Author contributions: MAT: look for ideas, put in proposals, & seek research fund; **EA & SM:** distribute questionnaires & analyze results; **FAY:** analyze & translate data; & **MIS:** evaluate word errors as well as template. All authors approve final version of the article.

Funding: This article was funded by the Ministry of Education and Culture through the PUDPT grant program contract number 196/E5/PG.02.00.PT/2022 and 2.6.49/UN32.20.1/LT/2022.

Ethics declaration: Authors declared that the procedure for implementing study ethics is regulated in the Guidelines for Writing Scientific Papers, PPKI, 2017 from the State University of Malang. This research also follows that rule. Authors further declared that data was collected from volunteer participants in online surveys. Personal data has been guaranteed to be kept confidential in this study.

Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

REFERENCES

Alalwan, N., Cheng, L., Al-Samarraie, H., Yousef, R., Ibrahim Alzahrani, A., & Sarsam, S. M. (2020). Challenges and prospects of virtual reality and augmented reality utilization among primary school teachers: A developing country perspective. *Studies in Educational Evaluation, 66*, 100876. https://doi.org/10.1016/j.stueduc.2020.100876

Alshurafat, H., Al Shbail, M. O., Masadeh, W. M., Dahmash, F., & Al-Msiedeen, J. M. (2021). Factors affecting online accounting education during the COVID-19 pandemic: An integrated perspective of social capital theory, the theory of reasoned action and the technology acceptance model. *Education and Information Technologies, 26*(6), 6995-7013. https://doi.org/10.1007/s10639-021-10550-y

Altarteer, S., & Charissis, V. (2019). Technology acceptance model for 3D virtual reality system in luxury brands online stores. *IEEE Access, 7*, 64053-64062. https://doi.org/10.1109/ACCESS.2019.2916353

Araiza-Alba, P., Keane, T., & Kaufman, J. (2022). Are we ready for virtual reality in K-12 classrooms? *Technology, Pedagogy and Education, 31*(4), 471-491. https://doi.org/10.1080/1475939X.2022.2033307

Barrera-Algarín, E., Sarasola-Sánchez-Serrano, J. L., & Sarasola-Fernández, A. (2021). Social work in the face of emerging technologies: A technological acceptance study in 13 countries. *International Social Work*. https://doi.org/10.1177/00208728211041672

Barrett, A., Pack, A., Guo, Y., & Wang, N. (2020). Technology acceptance model and multi-user virtual reality learning environments for Chinese language education. *Interactive Learning Environments*. https://doi.org/10.1080/10494820.2020.1855209

Beauducel, A., & Herzberg, P. Y. (2006). On the performance of maximum likelihood versus means and variance adjusted weighted least squares estimation in CFA. *Structural Equation Modeling: A Multidisciplinary Journal, 13*(2), 186-203. https://doi.org/10.1207/s15328007sem1302_2

Beldad, A. D., & Hegner, S. M. (2018). Expanding the technology acceptance model with the inclusion of trust, social influence, and health valuation to determine the predictors of German users' willingness to continue using a fitness app: A structural equation modeling approach. *International Journal of Human–Computer Interaction, 34*(9), 882-893. https://doi.org/10.1080/10447318.2017.1403220

Brooks, F. P. (1999). What's real about virtual reality? *IEEE Computer Graphics and Applications, 19*(6), 16-27. https://doi.org/10.1109/38.799723

Creswell, J. W. (2020). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Pearson Higher Ed.

Davis, F. D. (1985). *A technology acceptance model for empirically testing new end-user information systems: Theory and results* [PhD thesis, Massachusetts Institute of Technology].

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly: Management Information Systems, 13*(3), 319-339. https://doi.org/10.2307/249008

Davis, F. D., Bagozzi, R. P., &Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science, 35*(8), 982-1003. https://doi.org/10.1287/mnsc.35.8.982

Dong, Y., Xu, C., Chai, C. S., & Zhai, X. (2020). Exploring the structural relationship among teachers' technostress, technological pedagogical content knowledge (TPACK), computer self-efficacy and school support. *The Asia-Pacific Education Researcher, 29*(2), 147-157. https://doi.org/10.1007/s40299-019-00461-5

Doolani, S., Wessels, C., Kanal, V., Sevastopoulos, C., Jaiswal, A., Nambiappan, H., & Makedon, F. (2020). A Review of extended reality (XR) technologies for manufacturing training. *Technologies, 8*(4), 77. https://doi.org/10.3390/technologies8040077

Eraslan Yalcin, M., & Kutlu, B. (2019). Examination of students' acceptance of and intention to use learning management systems using extended TAM. *British Journal of Educational Technology, 50*(5), 2414-2432. https://doi.org/10.1111/bjet.12798

Eutsler, L., & Long, C. S. (2022). Preservice teachers' acceptance of virtual reality to plan science instruction. *International Forum of Educational Technology & Society, 24*(2), 24-48.

Fagan, M., Kilmon, C., & Pandey, V. (2012). Exploring the adoption of a virtual reality simulation: The role of perceived ease of use, perceived usefulness and personal innovativeness. *Campus-Wide Information Systems, 29*(2), 117-127. https://doi.org/10.1108/10650741211212368

Farrell, R., Cowan, P., Brown, M., Roulston, S., Taggart, S., Donlon, E., & Baldwin, M. (2022). Virtual reality in initial teacher education (VRITE): A reverse mentoring model of professional learning for learning leaders. *Irish Educational Studies, 41*(1), 245-256. https://doi.org/10.1080/03323315.2021.2021102

Fussell, S. G., & Truong, D. (2021). Accepting virtual reality for dynamic learning: An extension of the technology acceptance model. *Interactive Learning Environments, 0*(0), 1-18. https://doi.org/10.1080/10494820.2021.2009880

Granić, A., & Marangunić, N. (2019). Technology acceptance model in educational context: A systematic literature review. *British Journal of Educational Technology, 50*(5), 2572-2593. https://doi.org/10.1111/bjet.12864

Grassini, S., & Laumann, K. (2020). Are modern head-mounted displays sexist? A systematic review on gender differences in HMD-mediated virtual reality. *Frontiers in Psychology, 11*, 1604. https://doi.org/10.3389/fpsyg.2020.01604

Gurer, M. D. (2021). Examining technology acceptance of pre-service mathematics teachers in Turkey: A structural equation modeling approach. *Education and Information Technologies, 26*(4), 4709-4729. https://doi.org/10.1007/s10639-021-10493-4

Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: A systematic literature review of quantitative learning outcomes and experimental design. *Journal of Computers in Education, 8*(1), 1-32. https://doi.org/10.1007/s40692-020-00169-2

Han, D.-I. D., Bergs, Y., & Moorhouse, N. (2022). Virtual reality consumer experience escapes: Preparing for the metaverse. *Virtual Reality, 26*, 1443-1458. https://doi.org/10.1007/s10055-022-00641-7

Hayes, A., Daughrity, L. A., & Meng, N. (2021). Approaches to integrate virtual reality into K-16 lesson plans: An introduction for teachers. *TechTrends, 65*(3), 394-401. https://doi.org/10.1007/s11528-020-00572-7

Hernández-de-Menéndez, M., Vallejo Guevara, A., & Morales-Menendez, R. (2019). Virtual reality laboratories: A review of experiences. *International Journal on Interactive Design and Manufacturing, 13*(3), 947-966. https://doi.org/10.1007/s12008-019-00558-7

Hsu, C.-L., & Lu, H.-P. (2004). Why do people play on-line games? An extended TAM with social influences and flow experience. *Information & Management, 41*(7), 853-868. https://doi.org/10.1016/j.im.2003.08.014

Hwang, G.-J., & Chien, S.-Y. (2022). Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective. *Computers and Education: Artificial Intelligence, 3*, 100082. https://doi.org/10.1016/j.caeai.2022.100082

Ibili, E., Resnyansky, D., & Billinghurst, M. (2019). Applying the technology acceptance model to understand maths teachers' perceptions towards an augmented reality tutoring system. *Education and Information Technologies, 24*(5), 2653-2675. https://doi.org/10.1007/s10639-019-09925-z

Iqbal, S., & Ahmed Bhatti, Z. (2015). An investigation of university student readiness towards m-learning using technology acceptance model. *The International Review of Research in Open and Distributed Learning, 16*(4). https://doi.org/10.19173/irrodl.v16i4.2351

Jang, J., Ko, Y., Shin, W. S., & Han, I. (2021). Augmented reality and virtual reality for learning: An examination using an extended technology acceptance model. *IEEE Access, 9*, 6798-6809. https://doi.org/10.1109/ACCESS.2020.3048708

Joo, Y. J., Park, S., & Lim, E. (2018). Factors influencing preservice teachers' intention to use technology: TPACK, teacher self-efficacy, and technology acceptance model. *Journal of Educational Technology & Society, 21*(3), 48-59.

Kamal, S. A., Shafiq, M., & Kakria, P. (2020). Investigating acceptance of telemedicine services through an extended technology acceptance model (TAM). *Technology in Society, 60*, 101212. https://doi.org/10.1016/j.techsoc.2019.101212

Kaushik, M. K., & Agrawal, D. (2021). Influence of technology readiness in adoption of e-learning. *International Journal of Educational Management, 35*(2), 483-495. https://doi.org/10.1108/IJEM-04-2020-0216

Kemp, A., Palmer, E., Strelan, P., & Thompson, H. (2022). Exploring the specification of educational compatibility of virtual reality within a technology acceptance model. *Australasian Journal of Educational Technology, 38*(2), 15-34. https://doi.org/10.14742/ajet.7388

Kraus, S., Kanbach, D. K., Krysta, P. M., Steinhoff, M. M., & Tomini, N. (2022). Facebook and the creation of the metaverse: Radical business model innovation or incremental transformation? *International Journal of Entrepreneurial Behavior & Research, 28*(9), 52-77. https://doi.org/10.1108/IJEBR-12-2021-0984

Laurell, C., Sandström, C., Berthold, A., & Larsson, D. (2019). Exploring barriers to adoption of virtual reality through social media analytics and machine learning–An assessment of technology, network, price and trialability. *Journal of Business Research, 100*, 469-474. https://doi.org/10.1016/j.jbusres.2019.01.017

Lee, J., Kim, J., & Choi, J. Y. (2019). The adoption of virtual reality devices: The technology acceptance model integrating enjoyment, social interaction, and strength of the social ties. *Telematics and Informatics, 39*, 37-48. https://doi.org/10.1016/j.tele.2018.12.006

Legris, P., Ingham, J., & Collerette, P. (2003). Why do people use information technology? A critical review of the technology acceptance model. *Information & Management, 40*(3), 191-204. https://doi.org/10.1016/S0378-7206(01)00143-4

Lin, C.-H., Shih, H.-Y., & Sher, P. J. (2007). Integrating technology readiness into technology acceptance: The TRAM model. *Psychology and Marketing, 24*(7), 641-657. https://doi.org/10.1002/mar.20177

Liu, R., Wang, L., Lei, J., Wang, Q., & Ren, Y. (2020). Effects of an immersive virtual reality-based classroom on students' learning performance in science lessons. *British Journal of Educational Technology, 51*(6), 2034-2049. https://doi.org/10.1111/bjet.13028

Mahalil, I., Yusof, A. M., & Ibrahim, N. (2020). A literature review on the usage of technology acceptance model for analyzing a virtual reality's cycling sport applications with enhanced realism fidelity. In *Proceedings of the 8th International Conference on Information Technology and Multimedia* (pp. 237-242). https://doi.org/10.1109/ICIMU49871.2020.9243571

Mailizar, M., Burg, D., & Maulina, S. (2021). Examining university students' behavioral intention to use e-learning during the COVID-19 pandemic: An extended TAM model. *Education and Information Technologies, 26*(6), 7057-7077. https://doi.org/10.1007/s10639-021-10557-5

Manis, K. T., & Choi, D. (2019). The virtual reality hardware acceptance model (VR-HAM): Extending and individuating the technology acceptance model (TAM) for virtual reality hardware. *Journal of Business Research, 100*, 503-513. https://doi.org/10.1016/j.jbusres.2018.10.021

Marks, B., & Thomas, J. (2022). Adoption of virtual reality technology in higher education: An evaluation of five teaching semesters in a purpose-designed laboratory. *Education and Information Technologies, 27*(1), 1287-1305. https://doi.org/10.1007/s10639-021-10653-6

Matovu, H., Ungu, D. A. K., Won, M., Tsai, C.-C., Treagust, D. F., Mocerino, M., & Tasker, R. (2022). Immersive virtual reality for science learning: Design, implementation, and evaluation. *Studies in Science Education*. https://doi.org/10.1080/03057267.2022.2082680

Mayer, P., & Girwidz, R. (2019). Physics teachers' acceptance of multimedia applications–Adaptation of the technology acceptance model to investigate the influence of TPACK on physics teachers' acceptance behavior of multimedia applications. *Frontiers in Education, 4*, 73. https://doi.org/10.3389/feduc.2019.00073

Meyer, O. A., Omdahl, M. K., & Makransky, G. (2019). Investigating the effect of pre-training when learning through immersive virtual reality and video: A media and methods experiment. *Computers & Education, 140*, 103603. https://doi.org/10.1016/j.compedu.2019.103603

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Murgu, C. (2021). "A modern disease of adaptation …"?: Technostress and academic librarians working in digital scholarship at ARL institutions. *The Journal of Academic Librarianship, 47*(5), 102400. https://doi.org/10.1016/j.acalib.2021.102400

Mystakidis, S. (2022). Metaverse. *Encyclopedia, 2*(1), 486-497. https://doi.org/10.3390/encyclopedia2010031

Natasia, S. R., Wiranti, Y. T., & Parastika, A. (2022). Acceptance analysis of NUADU as e-learning platform using the technology acceptance model (TAM) approach. *Procedia Computer Science, 197*, 512-520. https://doi.org/10.1016/j.procs.2021.12.168

Ozgur, H. (2020). Relationships between teachers' technostress, technological pedagogical content knowledge (TPACK), school support and demographic variables: A structural equation modeling. *Computers in Human Behavior, 112*, 106468. https://doi.org/10.1016/j.chb.2020.106468

Page, R. L. (2000). Brief history of flight simulation. In *SimTecT 2000 Proceedings* (pp. 11-17).

Pal, D., & Vanijja, V. (2020). Perceived usability evaluation of Microsoft Teams as an online learning platform during COVID-19 using system usability scale and technology acceptance model in India. *Children and Youth Services Review, 119*, 105535. https://doi.org/10.1016/j.childyouth.2020.105535

Park, S. Y. (2009). An analysis of the technology acceptance model in understanding university students' behavioral intention to use e-learning. *Educational Technology & Society, 12*(3), 150-161.

Parong, J., & Mayer, R. E. (2018). Learning science in immersive virtual reality. *Journal of Educational Psychology, 110*(6), 785-797. https://doi.org/10.1037/edu0000241

Parong, J., & Mayer, R. E. (2021). Cognitive and affective processes for learning science in immersive virtual reality. *Journal of Computer Assisted Learning, 37*(1), 226-241. https://doi.org/10.1111/jcal.12482

Perret, J., & Vander Poorten, E. (2018). Touching virtual reality: A review of haptic gloves. In *Proceedings of the 16th International Conference on New Actuators ACTUATOR 2018* (pp. 1-5).

Rahimi, B., Nadri, H., Afshar, H. L., & Timpka, T. (2018). A systematic review of the technology acceptance model in health informatics. *Applied Clinical Informatics, 09*(3), 604-634. https://doi.org/10.1055/s-0038-1668091

Ranellucci, J., Rosenberg, J. M., & Poitras, E. G. (2020). Exploring pre-service teachers' use of technology: The technology acceptance model and expectancy–value theory. *Journal of Computer Assisted Learning, 36*(6), 810-824. https://doi.org/10.1111/jcal.12459

Rospigliosi, P. (2022). Metaverse or simulacra? Roblox, Minecraft, Meta and the turn to virtual reality for education, socialization and work. *Interactive Learning Environments, 30*(1), 1-3. https://doi.org/10.1080/10494820.2022.2022899

Safikhani, S., Keller, S., Schweiger, G., & Pirker, J. (2022). Immersive virtual reality for extending the potential of building information modeling in architecture, engineering, and construction sector: Systematic review. *International Journal of Digital Earth, 15*(1), 503-526. https://doi.org/10.1080/17538947.2022.2038291

Sagnier, C., Loup-Escande, E., Lourdeaux, D., Thouvenin, I., & Valléry, G. (2020). User acceptance of virtual reality: An extended technology acceptance model. *International Journal of Human-Computer Interaction, 36*(11), 993-1007. https://doi.org/10.1080/10447318.2019.1708612

Salloum, S. A., Qasim Mohammad Alhamad, A., Al-Emran, M., Abdel Monem, A., & Shaalan, K. (2019). Exploring students' acceptance of e-Learning through the development of a comprehensive technology acceptance model. *IEEE Access, 7*, 128445-128462. https://doi.org/10.1109/ACCESS.2019.2939467

Scherer, R., Siddiq, F., & Tondeur, J. (2019). The technology acceptance model (TAM): A meta-analytic structural equation modeling approach to explaining teachers' adoption of digital technology in education. *Computers & Education, 128*, 13-35. https://doi.org/10.1016/j.compedu.2018.09.009

Schmid, M., Brianza, E., & Petko, D. (2021). Self-reported technological pedagogical content knowledge (TPACK) of pre-service teachers in relation to digital technology use in lesson plans. *Computers in Human Behavior, 115*, 106586. https://doi.org/10.1016/j.chb.2020.106586

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education, 42*(2), 27. https://doi.org/10.1080/15391523.2009.10782544

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-21. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Solmaz, S., & Van Gerven, T. (2022). Interactive CFD simulations with virtual reality to support learning in mixing. *Computers & Chemical Engineering, 156*, 107570. https://doi.org/10.1016/j.compchemeng.2021.107570

Sukendro, S., Habibi, A., Khaeruddin, K., Indrayana, B., Syahruddin, S., Makadada, F. A., & Hakim, H. (2020). Using an extended technology acceptance model to understand students' use of e-learning during COVID-19: Indonesian sport science education context. *Heliyon, 6*(11), e05410. https://doi.org/10.1016/j.heliyon.2020.e05410

Sukotjo, C., Schreiber, S., Li, J., Zhang, M., Chia-Chun Yuan, J., & Santoso, M. (2021). Development and student perception of virtual reality for implant surgery. *Education Sciences, 11*(4), 176. https://doi.org/10.3390/educsci11040176

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education, 48*(6), 1273-1296. https://doi.org/10.1007/s11165-016-9602-2

Thohir, M. A., Jumadi, J., & Warsono, W. (2022). Technological pedagogical content knowledge (TPACK) of pre-service science teachers: A Delphi study. *Journal of Research on Technology in Education, 54*(1), 127-142. https://doi.org/10.1080/15391523.2020.1814908

Thohir, M. A., Yuliati, L., Ahdhianto, E., Untari, E., & Yanti, F. A. (2021). Exploring the relationship between personality traits and TPACK-web of pre-service teacher. *Contemporary Educational Technology, 13*(4), 16. https://doi.org/10.30935/cedtech/11128

To, W. M., & Tang, M. N. F. (2019). Computer-based course evaluation: An extended technology acceptance model. *Educational Studies, 45*(2), 131-144. https://doi.org/10.1080/03055698.2018.1443797

Tsivitanidou, O. E., Georgiou, Y., & Ioannou, A. (2021). A learning experience in inquiry-based physics with immersive virtual reality: Student perceptions and an interaction effect between conceptual gains and attitudinal profiles. *Journal of Science Education and Technology, 30*(6), 841-861. https://doi.org/10.1007/s10956-021-09924-1

Vallade, J. I., Kaufmann, R., Frisby, B. N., & Martin, J. C. (2021). Technology acceptance model: Investigating students' intentions toward adoption of immersive 360° videos for public speaking rehearsals. *Communication Education, 70*(2), 127-145. https://doi.org/10.1080/03634523.2020.1791351

Valtonen, T., Sointu, E., Kukkonen, J., Mäkitalo, K., Hoang, N., Häkkinen, P., Järvelä, S., Näykki, P., Virtanen, A., Pöntinen, S., Kostiainen, E., & Tondeur, J. (2019). Examining pre-service teachers' technological pedagogical content knowledge as evolving knowledge domains: A longitudinal approach. *Journal of Computer Assisted Learning, 35*(4), 491-502. https://doi.org/10.1111/jcal.12353

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46*(2), 186-204. https://doi.org/10.1287/mnsc.46.2.186.11926

Xi, N., Chen, J., Gama, F., Riar, M., & Hamari, J. (2022). The challenges of entering the metaverse: An experiment on the effect of extended reality on workload. *Information Systems Frontiers*. https://doi.org/10.1007/s10796-022-10244-x

Xiong, J., Hsiang, E.-L., He, Z., Zhan, T., & Wu, S.-T. (2021). Augmented reality and virtual reality displays: Emerging technologies and future perspectives. *Light: Science & Applications, 10*(1), 216. https://doi.org/10.1038/s41377-021-00658-8

Yang, J., Wang, Q., Wang, J., Huang, M., & Ma, Y. (2021). A study of K-12 teachers' TPACK on the technology acceptance of e-schoolbag. *Interactive Learning Environments, 29*(7), 1062-1075. https://doi.org/10.1080/10494820.2019.1627560

Yang, Y., & Wang, X. (2019). Modeling the intention to use machine translation for student translators: An extension of technology acceptance model. *Computers & Education, 133*, 116-126. https://doi.org/10.1016/j.compedu.2019.01.015

APPENDIX A

Table A1. Item survey instrument to identify connection between TAM, TPACK, and FC

Variables	Definition	Code	Item	References
TPACK	Integrating VR into classroom learning	TPACK1	I combine content, VR media, & learning methods in classroom	Jang et al. (2021)
		TPACK2	I am able to arrange lesson plans according to content of lesson, as well as its application using VR	
		TPACK3	I am able to develop VR-based lesson plans according to content	
		TPACK4	I have the ability to adapt VR to evaluate learning outcomes	
Facility condition (FC)	Availability of tools & facilities to support VR adoption	FC1	I have the resources I need to use VR	Kemp et al. (2022) & Park (2009)
		FC2	Instructions on using VR have been available to me	
		FC3	I have a device that supports VR	
		FC4	Help has been available for difficult VR usage	
Perceived usefulness (PU)	Perceived usefulness in using VR	PU1	I think VR helps students learn faster	Davis (1989)
		PU2	I think VR enables the achievement of learning goals	
		PU3	I think VR make learning easier	
		PU4	I think VR is useful for learning	
		PU5	I think VR enables improvement of learning outcomes	
Perceived ease of use (PEOU)	Perceived ease of use in using VR	PEOU1	I think VR is easy to operate, to help students learn faster	Davis (1989)
		PEOU2	I think VR makes it easier for students to achieve goals	
		PEOU3	I think the use of VR is clear and understandable	
		PEOU4	I find that VR is flexible to use	
		PEOU5	I think VR is easy to use	
Behavior intention (BI)	VR usage intensity	BI1	I intend to use VR later	Davis (1989), Fussell and Truong (2021), & Park (2009)
		BI2	I intend to become a VR user in the future	
		BI3	I recommend using VR to others later	
		BI4	I will be keen to see the development of VR in learning	