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**Research Article**

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

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**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

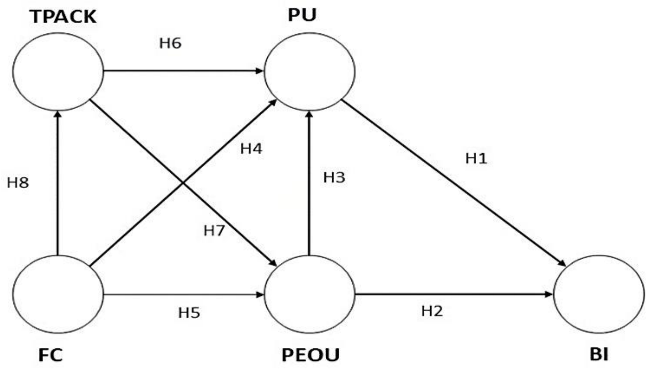


**Figure 1.** Hypothetical model (Source: Authors' own elaboration)

(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%)<br>Female=348 (85.7%) | | | | |
| VR knowledge | Knowing VR=303 (74.6%)<br>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.

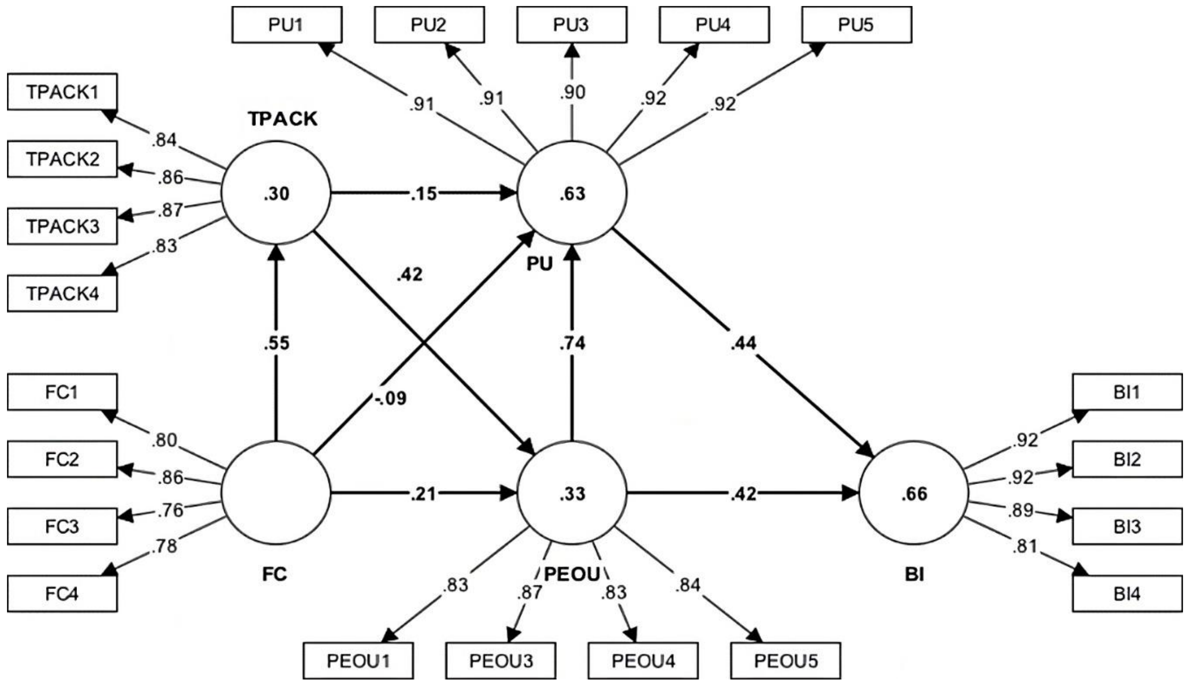


**Figure 2.** SEM VR acceptance of prospective teachers & its relationship with TPACK & FC (Source: Authors' own elaboration)

### 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 ($\beta$=.74) and FC->TPACK ($\beta$=.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.

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**Declaration of interest:** Authors declare no competing interest.

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

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# 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 | |