Lim et al. Int J Educ Technol High Educ (2024) 21:36
https://doi.org/10.1186/s41239-024-00472-3

International Journal of Educational Technology in Higher Education

RESEARCH ARTICLE **Open Access**

Student acceptance towards AsepticTech VR: a teaching and learning tool for cell and tissue culture aseptic techniques

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Abstract

The high cost of establishing a cell and tissue culture facility has denied students an opportunity to practice proper aseptic techniques during their studies. An in-house application named AsepticTech Virtual Reality (VR) was developed to simulate a cell and tissue culture facility for students to train their aseptic techniques virtually. However, the performance gain associated with the application will be limited by the student's willingness to use the application. Therefore, this study aims to investigate the driving factors behind students' intention to use AsepticTech VR. A total of 55 biomedical undergraduates were granted access to AsepticTech VR. After using the application, the students completed a Technology Acceptance Model (TAM) questionnaire. It measures seven latent constructs that are believed to influence the students' behavioral intention to use the application, namely Perceived Usefulness (PU), Perceived Ease of Use (PEU), Attitude Towards Use (ATU), Behavioral Intention (BI), Perceived Enjoyment (PENJ), Perceived Health Risk (PHR) and Self-Efficacy (SE). The questionnaire was preliminarily evaluated on its validity and reliability using Confirmatory Factor Analysis (CFA), Average Variance Extracted (AVE), Composite Reliability (CR), and Cronbach's alpha. Subsequently, the interactions between the seven latent variables were analyzed via path analysis. Findings of the path analysis suggested that ATU is the most influential factor on BI, followed by PENJ and SE. In turn, ATU was positively and significantly influenced by PENJ, whereas PHR exerted a significant negative influence on ATU. This study revealed that enjoyment and comfort are the principal factors influencing students' acceptance of AsepticTech VR. This study also identifies other determinants that influence users' acceptance of AsepticTech VR and paves guidance for the future development of the application.

Keywords: Aseptic techniques, Virtual reality, Technology acceptance model, Cell and tissue culture

Introduction

The aseptic technique is a collection of skills practiced in cell and tissue culture that aims to prevent contamination in the laboratory (Bykowski et al., 2019). A proper aseptic technique maintains the sterility of the cell lines and reagents and prevents contamination that may incur biological alterations and affect experimental results (Stacey, 2011). An example of such a catastrophe is the discovery of widespread mycoplasma contamination in cell lines used in previous research. Hence, this discovery raised concerns over the integrity of prior results and highlighted the importance of practicing proper aseptic techniques in cell and tissue culture (Drexler et al., 2003).

Despite the significance of aseptic techniques, the lack of actual cell and tissue culture facilities in higher learning institutions poses a problem for undergraduates to train these skills (David et al., 2020). The inability to practice these skills led to decreased learning performance and a lack of interest in acquiring aseptic techniques (Dyrberg et al., 2017; Hurst-Kennedy et al., 2020). Nonetheless, it has been reported that non-traditional learning methods, such as remote learning, may result in comparable learning outcomes if structured carefully (Brinson, 2015). Therefore, Virtual Reality (VR) technology presents as an attractive teaching and learning platform for aseptic techniques due to the numerous tangible and intangible benefits it offers, especially in the field of education (Reen et al., 2021; Strojny & Dużmańska-Misiarczyk, 2023; Yildirim et al., 2020).

In general, VR refers to technologies that permit user immersion and presence in a digitally created three-dimensional virtual environment, with the opportunity to interact with the components within said environment (Kardong-Edgren et al., 2019). To address the lack of facilities for teaching and learning activities, an in-house VR application named AsepticTech VR was developed. The application simulates a cell and tissue culture facility for students to practice aseptic techniques. The application consists of six modules that aim to train students on the aseptic techniques required during different cell and tissue culture workflow phases. In the application, users are guided via instructions to complete a subculture task and assessed via several question-and-answer prompts along the way.

Prior work by the authors suggested that AsepticTech VR can improve cognitive and psychomotor learning performance among users with regard to aseptic techniques. The application also elicited positive emotions and user experience; therefore, it was proposed as an ideal teaching and learning tool for its purpose. Despite these findings, its acceptance among the students remains unknown. Technology cannot fulfil its purpose without being accepted and used; thus, good technology should be able to provoke the user's intention to use to deliver its intended benefit.

Concurrent with this notion, Davis (1989) developed the Technology Acceptance Model (TAM) to investigate the intrinsic and extrinsic variables influencing users' intention to use a given technology. Since its pioneer development, TAM has expanded to accommodate various intrinsic and extrinsic factors (Venkatesh & Davis, 2000; Venkatesh et al., 2008). It has been among the most frequently used models to explain technology acceptance in various studies. In the field of education, TAM has also been widely used to assess the acceptance of educational technology, such as in the use of computer-based assessment (Maqableh et al., 2015), e-learning (Hernandez, 2021; Ibrahim et al., 2018), and the application of VR in learning (Majid & Shamsudin, 2019).

This study aims to investigate the aspects of AsepticTech VR that play a principal part in driving behavioral intention among students to utilize the application, which may serve as guidance on the future developmental direction of the application.

Technology Acceptance Model (TAM)

The TAM framework is widely employed to investigate the extrinsic and intrinsic factors that drive user intention to accept and use a particular technology. Today, several versions of TAM exist, catering to the specific factors investigated within the context of the respective studies that employ the model. Understandably, as the application of VR increases, more studies (Fussell & Truong, 2022; Majid & Shamsudin, 2019; Sagnier et al., 2020) are currently adopting the TAM framework to examine user intention to use VR.

The TAM utilized in this study was adapted from the extended TAM model proposed by Fussell and Truong (2022) with some modifications. Seven main factors were selected based on relevance to this study, namely Perceived Usefulness (PU), Perceived Ease of Use (PEU), Attitude towards Use (ATU), Behavioral Intention (BI), Perceived Enjoyment (PENJ), Perceived Health Risk (PHR) and Self-Efficacy (SE). The respective factors are explained in detail in the following sections.

Perceived Usefulness (PU) and Perceived Ease of Use (PEU)

PU and PEU are the two principal predictors of ATU with regard to technology, according to the initial TAM model (Davis et al., 1989).

In the mentioned study, PU was defined as "the degree to which a user believes that using a particular technology or system would enhance his or her job performance." Meanwhile, PEU was defined as "the degree to which a user believes that using a particular technology would be free of effort." In the context of this study, PU can be understood as the extent to which a student believes that using AsepticTech VR would enhance their learning performance in terms of cell and tissue culture aseptic techniques. At the same time, PEU refers to the extent to which AsepticTech VR is perceived as easy and of little effort to use.

In the TAM model by Davis et al. (1989), PU and PEU are proven to be significant predictors of ATU, which in turn predicts BI, as displayed in Fig. 1. In other words, ATU, which refers to the interest of a user to utilize a particular technology will be determined by how useful the technology is (PU) and how easy it is to use said technology (PEU). These two relationships were also frequently validated in later studies (Cheung & Vogel, 2013; Fussell & Truong, 2022; Zheng & Li, 2020). These two relationships appear to hold in the context of VR technology, as the following VR-related studies that employ TAM also supported this influence (Fussell & Truong, 2022; Manis & Choi, 2019). Besides its direct influence on ATU, some studies have also revealed that PU may also mediate the influence of PEU on ATU. Specifically, PEU was determined to influence PU; the more effortless a technology is for the user to use, the more useful it will be perceived. This relationship is also consistently validated in later studies (Fussell & Truong, 2022; Majid & Shamsudin, 2019; Manis & Choi, 2019; Maqableh et al., 2015; Sagnier et al., 2020). The following hypotheses are hence formulated:

H1: PU has a significant influence on ATU.
H2: PEU has a significant influence on ATU.
H3: PEU has a significant influence on PU.

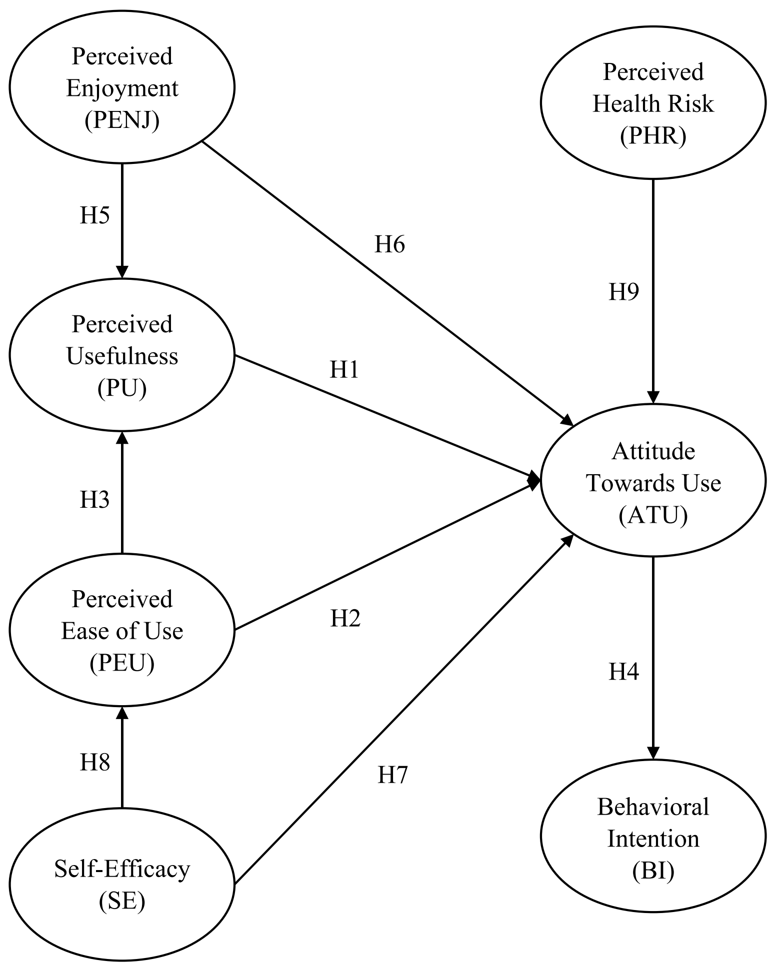

Fig. 1 A path diagram illustrating seven interacting factors investigated in this study, with the arrowheads (H1-H9) displaying the direction of influences among the variables

Attitude Towards Use (ATU)

The next predictor, ATU, is also a predictor for BI to use a technology proposed by the initial TAM model in 1989. ATU was defined as "the extent of positive or negative evaluation a user has towards a technology," be it evaluation in the form of "like or dislike" or "favorable or unfavorable." Similarly, in the context of this study, ATU refers to the degree to which a student has a favorable or unfavorable appraisal or evaluation of VR for cell culture.

As illustrated in Fig. 1, ATU was demonstrated to be an antecedent to BI in predicting users' acceptance of a technology. In other words, users tend to have the intention to use a technology that they positively evaluate or believe will bring about a positive effect. The influence of ATU on BI has also been validated in more recent studies (Fussell & Truong, 2022; Huang et al., 2023; Manis & Choi, 2019). Therefore, the same hypothesis will be formulated to investigate whether the relationship still exists within the context of our study:

H4: ATU has a significant influence on BI.

Behavioral Intention (BI)

BI can be considered the dependent variable or the outcome variable of interest in this study. BI is defined as "the extent to which a user is willing to try and use a technology or the effort they are planning to exert in using a particular technology." The context of this study refers to the willingness of students to use AspeticTech VR to practice cell and tissue culture aseptic techniques.

In the initial TAM model, BI was the immediate antecedent to usage behavior (Davis et al., 1989). Therefore, determining the overall BI for a particular technology is apparently of utmost importance in determining the overall usage exhibited by potential users. Therefore, TAM is employed to determine which factors directly or indirectly influence BI to understand the factors influencing students' acceptance of AsepticTech VR as a teaching and learning tool for aseptic techniques.

In the initial TAM model, BI was the immediate antecedent to usage behavior (Davis et al., 1989). Therefore, determining the overall behavioral intention for a particular technology is apparently of utmost importance in determining the overall usage exhibited by potential users. Therefore, TAM is employed to determine which factors are directly or indirectly influencing BI to understand the factors that influence students' acceptance towards AsepticTech VR as a teaching and learning tool for aseptic techniques.

Perceived Enjoyment (PENJ)

Hedonic qualities such as enjoyment associated with the use of technology were not part of the constructs considered in the original TAM. However, hedonic qualities of technology have been proven to indirectly affect behaviors by influencing user emotions, as cited in Sagnier et al. (2020). Therefore, PENJ is a vital construct to consider when investigating the factors that may influence BI's use of technology. PENJ is defined as "the extent to which a user enjoys the experience associated with the use of a technology, regardless of the expectation on the performance or outcome of said usage." In the context of this study, PENJ refers to the extent to which using AsepticTech VR for cell culture training is perceived to be enjoyable, apart from the performance consequences that may be anticipated.

Among the commonly external variables used as constructs in TAM, PENJ was the best predictor for PU based on an extensive meta-analysis by Abdullah and Ward (2016). Therefore, this led to the formulation of the following hypothesis:

H5: PENJ significantly influences PU.

Besides its influence on PU, PENJ was also postulated to be able to influence ATU. In their study, Manis and Choi (2019) postulated that the hedonic quality of VR technology positively influences the attitude of users towards the technology, and a significant association was indeed reported. This finding was further validated by Fussell and Truong (2022). Due to the association, the following hypothesis was formulated:

H6: PENJ significantly influences ATU.

Self-Efficacy (SE)

Gong et al. (2004) incorporated the SE construct into the conceptual framework due to the emphasis of TAM on the users' sole perception about the technology, leaving other cognitive components that may also influence usage behaviors unconsidered.

As cited in their paper, SE was coined by Bandura (1986) and defined as "one's belief in one's capability to organize and execute a specific action to achieve a desired performance." In the context of this study, SE can be defined as the belief or confidence of the students in their own cell and tissue culture skills in both the actual and virtual environment. Unsurprisingly, SE was discovered to influence one's BI to use technology, as depicted by Compeau and Higgins (1995). However, as mentioned by Fussell and Truong (2022), the influence exerted by SE on BI yielded mixed results. Additionally, it was postulated that said influence may be due to SE affecting the users' appraisal (ATU) of the technology itself, and such a statement is supported by some later studies (Chow et al., 2012). The next hypothesis was therefore formulated as follows:

H7: SE significantly influences ATU.

However, SE has also been considered an antecedent to PEU, with this association noted as early as the Davis et al. (1989) study. This association is later reiterated by Venkatesh and Davis (1996), who reported that users' PEU is formed based on their SE towards technology. This judgement is made prior to using the technology and is regardless of the extent of instructions given to the users on how to use the system. Unsurprisingly, this relationship has also been validated in subsequent studies (Fussell & Truong, 2022; Maqableh et al., 2015; Zheng & Li, 2020). Similarly, the meta-analysis by Abdullah and Ward (2016) revealed SE as the best commonly used external predictor for PEU. Therefore, with the above information, the following hypothesis was formulated:

H8: SE significantly influences PEU.

Perceived Health Risk (PHR)

Users of VR technology often encounter motion sickness-like symptoms, including dizziness, nausea, and headache in the absence of physical motion. These symptoms are collectively referred to as cybersickness and are commonly reported in situations where VR is used (Rebenitsch & Owen, 2016). A previous study categorizes symptoms experienced in cybersickness under three main categories, namely nausea, oculomotor, and disorientation (Kennedy et al., 1993).

Regardless of the symptoms, cybersickness represents a PHR by the users and results in an uncomfortable experience. It has been attributed as a factor that may deter future usage, and its inverse relationship with BI has been reported previously (Fussell & Truong, 2022; Sagnier et al., 2020). However, since ATU is an established antecedent of BI, certain studies reported a significant influence of PHR on ATU instead (Koh et al., 2023). Based on this information, the following hypothesis is formulated:

H9: PHR significantly influences ATU.

Figure 1 below summarizes the hypothesized inter-factor influences that are formulated.

Methodology

This study aims to assess the level of acceptance towards AsepticTech VR alongside the driving factors that influence the students' BI to use the application for learning cell and tissue culture aseptic techniques. The task was achieved using a TAM questionnaire.

AsepticTech VR Application

AsepticTech VR Application is an in-house developed VR application that aims to simulate a real cell and tissue culture laboratory. The application was developed on the Unity® Platform (version 2018.4.13f1) and is compatible with smartphones using Android operating system 5.1 and above. To use the application, participants only need to mount their mobile device on a headset to start their VR application.

The AsepticTech VR application aims to serve as a tool to familiarize and train users with the aseptic techniques associated with cell and tissue culture. The content is fully developed based on the course outline of the undergraduate course SBP3410 Cell and Tissue Culture. Within the application, users were tasked to perform subculture on a flask of murine macrophages. To complete the task, the application will guide the users through six modules that encompasses all aspects of cell and tissue culture aseptic technique, starting from (1) donning a proper attire for cell and tissue culture work, (2) choosing an appropriate BSC, (3) preparing for cell and tissue culture work, (4) examining for contamination, (5) performing a subculture, and (6) finally wrapping up their work. Quizzes were also included at several checkpoints to assess the users' understanding alongside immediate feedback based on the inputted answer.

Figure 2 displays a screenshot of the application showing a BSC, and other cell-and-tissue-culture-related items.

Participants

The sample population of this study consists of biomedical science undergraduates taking the course SBP3410 Cell and Tissue Culture at Universiti Putra Malaysia. An announcement was made in class to recruit study participants, and students were briefed about the overall study design, the study aims, and the risks and benefits to expect from participating in the study. A form containing the same information in written form was also distributed to obtain informed consent from students who decided to participate in the study. To address potential conflicts of interest, students were also made clear that participation should only be voluntary and that their responses in this study would not affect their grades in the course. Of 58 students enrolled in SBP3410, a total of 55 students provided their informed consent to participate in the study.

Study design

The TAM questionnaire used in this study was adopted from Fussell and Truong (2022) to quantitatively measure the seven constructs mentioned above. In total, 28 Likert scale questions were included in the TAM questionnaire. Each question presents a statement

Fig. 2 A screenshot of a scene in AsepticTech VR application

to which the participant will express their degree of agreement (1 = Strongly disagree, 5 = Strongly agree). The items are listed in Supplementary Material.

The study was conducted in the form of a cross-sectional study. Participants were first granted access to the AsepticTech VR application, which used the application to complete all modules within the application. Upon completing the modules within the application, students were given the TAM questionnaire through Google Forms and were required to answer all presented questions.

Data analysis

The data analysis consisted of three main sections. First, data were subjected to descriptive statistical analysis to obtain a general information picture. Second, the validity of the questionnaire was assessed via Confirmatory Factor Analysis (CFA) and Average Variance Extracted (AVE). Furthermore, the reliability of the questionnaire was assessed via Composite Reliability (CR) and Cronbach's alpha. Meanwhile, the content validity of the questionnaire was ensured by selecting a subset of questions from the study by Fussell and Truong (2022) that are relevant to the study. Thirdly, path analysis was performed to determine the impact between the latent variable and detect significant influences.

Descriptive statistics and calculation of Cronbach's alpha were performed via IBM Statistical Package for the Social Sciences (SPSS) version 26, whereas CFA and path analysis were performed on IBM SPSS AMOS version 26.

Results

Descriptive Statistics

Table 1 provides the descriptive statistics of the responses collected from the 55 respondents via the TAM questionnaire. On average, the respondents exhibited relatively positive responses towards the seven latent constructs assessed. Among the seven latent constructs, participants appear to score the highest on ATU (mean = 4.27), followed by PENJ (mean = 4.26) and PU (mean = 4.27). In other words, most of the students think that AsepticTech VR is acceptable due to their own attitude towards using

Table 1 Descriptive statistics of responses to individual items in the questionnaire (*N* = 55)

Item	Question	Mean ± SD
PU		4.26 ± 0.68
PU1	Using AsepticTech VR in my learning process would enable me to accomplish cell culture tasks more quickly	4.25 ± 0.75
PU2	Using AsepticTech VR would improve my cell culture performance	4.25 ± 0.72
PU3	Using AsepticTech VR in my learning process would increase my productivity	4.13 ± 0.90
PU4	Using AsepticTech VR would enhance my effectiveness on the cell culture task	4.27 ± 0.84
PU5	Using AsepticTech VR would make it easier to do cell culture	4.36 ± 0.77
PU6	I would find using AsepticTech VR useful in my learning	4.35 ± 0.77
PEU		4.00 ± 0.67
PEU1	Learning to operate AsepticTech VR is easy for me	4.18 ± 0.92
PEU2	I find it easy to get AsepticTech VR to do what I want it to do	3.85 ± 0.93
PEU3	My interaction with AsepticTech VR is clear and understandable	3.91 ± 0.88
PEU4	I find AsepticTech VR to be flexible to interact with	3.95 ± 0.91
PEU5	It would be easy for me to become skillful at using AsepticTech VR	4.07 ± 0.79
PEU6	I find AsepticTech VR easy to use	4.07 ± 0.90
ATU		4.27 ± 0.78
ATU1	Using AsepticTech VR for cell culture training is a good idea	4.33 ± 0.77
ATU2	Using AsepticTech VR for cell culture training is a wise idea	4.22 ± 0.91
ATU3	I feel positively toward using AsepticTech VR for cell culture training	4.27 ± 0.80
BI		4.16 ± 0.88
BI1	If made available, I am willing to use AsepticTech VR for cell culture training	4.22 ± 0.87
BI2	If made available, I intend to use AsepticTech VR for cell culture training	4.20 ± 0.95
BI3	If made available, I intend to use every cell culture training lesson provided through AsepticTech VR	4.09 ± 1.02
PENJ		4.26 ± 0.79
PENJ1	Using AsepticTech VR for cell culture training would be enjoyable	4.24 ± 0.98
PENJ2	Using AsepticTech VR for cell culture training would be exciting	4.25 ± 0.90
PENJ3	I enjoy using immersive simulation technology such as AsepticTech VR	4.25 ± 0.82
PENJ4	I have fun using immersive simulation technology such as AsepticTech VR	4.31 ± 0.76
PHR		3.81 ± 0.78
PHR1	Using AsepticTech VR for cell culture training may negatively affect my physical health	3.38 ± 1.31
PHR2	Using AsepticTech VR for cell culture training is safer for me physically than using a cell culture training device	3.95 ± 1.12
PHR3	Using AsepticTech VR for cell culture training is safer for me physically than using an actual cell culture biosafety cabinet/hood	4.13 ± 0.86
SE		4.08 ± 0.80
SE1	I feel confident in my ability to use AsepticTech VR for cell culture training	4.18 ± 0.88
SE2	I feel confident that my cell culture skills will make cell culturing in AsepticTech VR easy	4.09 ± 0.94
SE3	I feel confident in my cell culture skills in the real-world environment	3.98 ± 0.93

the application, as well as the PENJ of the application and the fact that the students view the application as useful for their learning.

Validity and Reliability

CFA was performed using SPSS Amos version 26 to assess the validity and reliability of each item and respective construct. First, the individual items were screened based on their loading factors. One recommendation commonly referred to is that a loading factor value above 0.5 reflects good indicator reliability (Hair, 1995). All but one item had an adequate loading factor based on this criterion, with their loading factors ranging from 0.607 to 0.942. PHR1, however, was the only item to fail this criterion with a loading factor of 0.101.

Furthermore, to assess the convergent validity, AVE was calculated for all seven latent constructs used in the study. It is recommended that the AVE value exceed a minimum of 0.5 to claim adequate convergent validity (Hair, 2009). Based on the statement, five of the seven factors had attained good convergent validity, except for PEU and PHR, with an AVE of 0.490 and 0.430, respectively.

Furthermore, the internal consistency of the items was determined via measurement of CR and Cronbach's alpha of the seven separate constructs. In general, items with CR and Cronbach's alpha values above 0.70 are considered to have high internal consistency. An initial calculation revealed that PHR had a low internal consistency with a CR value of 0.625 and Cronbach's alpha value of 0.489.

Upon further inspection, item PHR1 was proven to have low correlations compared to PHR2 and PHR3. On the basis of the results of validity and reliability measurements, PHR1 was excluded from the questionnaire due to its potential role in negatively impacting the validity and reliability of the construct PHR. The removal of item PHR1 increased the AVE of PHR to 0.635, CR to 0.774, and Cronbach's alpha to 0.746, all of which exceeded their respective minimum recommended values. The validity and reliability measures used and their respective values following the removal of PHR1 are summarized in Table 2.

Furthermore, the discriminant validity was also evaluated based on the AVE value. A construct is claimed to have sufficient discriminant validity if its AVE value exceeds all squared correlation coefficients (R^2) with other constructs (Fornell & Larcker, 1981). The AVE and R^2 values are tabulated in Table 3. As observed, six out of seven constructs demonstrated adequate discriminant validity. However, PEU may be associated with discriminant validity issues.

Path analysis

Path analysis determined the significance of the postulated influences between the seven latent variables. As shown in Fig. 1, every latent variables influence BI via direct or indirect mechanisms. ATU, for instance, has direct impact on BI, whereas the other variables exert their influence on BI indirectly, mediated through ATU. Table 4 provides the direct and indirect impact each individual factor has on the dependent factor BI.

In addition, the path coefficient, *t*-value, and *p*-value for the respective influences analyzed in this study, or paths, are summarized in Table 5. In short, among the nine hypotheses tested, six revealed a significant result (H3, H4, H5, H6, H8, H9). The

Table 2 Construct validity and internal consistency of the items after removal of item PHR1

Construct	Items	Factor Loading (> 0.5)	AVE (> 0.5)	CR (> 0.7)	Cronbach's Alpha (> 0.7)
Perceived Usefulness	PU1	0.782	0.695	0.932	0.930
	PU2	0.841			
	PU3	0.890			
	PU4	0.764			
	PU5	0.849			
	PU6	0.868			
Perceived Ease of Use	PEU1	0.626	0.490	0.850	0.846
	PEU2	0.607			
	PEU3	0.782			
	PEU4	0.784			
	PEU5	0.748			
	PEU6	0.627			
Attitude Towards Use	ATU1	0.938	0.841	0.941	0.938
	ATU2	0.874			
	ATU3	0.937			
Behavioral Intention	BI1	0.921	0.808	0.926	0.917
	BI2	0.942			
	BI3	0.830			
Perceived Enjoyment	PENJ1	0.878	0.778	0.934	0.931
	PENJ2	0.894			
	PENJ3	0.868			
	PENJ4	0.889			
Perceived Health Risk	PHR2	0.696	0.635	0.774	0.746
	PHR3	0.886			
Self-Efficacy	SE1	0.838	0.651	0.846	0.839
	SE2	0.913			
	SE3	0.646			

Table 3 AVE of the seven constructs (bolded values) and the associated R^2 values (non-bolded values)

	PU	PEU	ATU	BI	PENJ	PHR	SE
PU	**0.695**						
PEU	0.582	**0.490**					
ATU	0.659	0.537	**0.842**				
BI	0.637	0.415	0.566	**0.808**			
PENJ	0.630	0.441	0.590	0.686	**0.778**		
PHR	0.450	0.331	0.312	0.539	0.483	**0.635**	
SE	0.484	0.423	0.442	0.410	0.404	0.483	**0.651**

three paths that did not exhibit significant results are PU → ATU, PEU → ATU and SE → ATU.

For the six paths that demonstrated significance, the interpretation of the results is as follows. First, H3 proves that PEU has a significant positive influence on PU,

Table 4 The magnitude of direct, indirect, and total effects on BI by other six factors

Factor	Direct Effects on BI	Indirect Effects on BI	Total Effect on BI
PU	0.000	0.349	0.349
PEU	0.000	0.314	0.314
ATU	0.816	0.000	0.816
PENJ	0.000	0.498	0.498
SE	0.000	0.467	0.467
PHR	0.000	-0.183	-0.183

Table 5 Path analysis of the seven latent variables

Hypothesis	Path	Path coefficient	t	*p*-value	Result
H1	PU → ATU	0.385	1.866	0.062	Not supported
H2	PEU → ATU	0.176	0.830	0.407	Not supported
H3	PEU → PU	0.653	4.153	< 0.001	Supported
H4	ATU → BI	0.816	6.127	< 0.001	Supported
H5	PENJ → PU	0.595	5.382	< 0.001	Supported
H6	PENJ → ATU	0.381	2.582	0.010	Supported
H7	SE → ATU	0.241	1.691	0.091	Not supported
H8	SE → PEU	0.773	3.580	< 0.001	Supported
H9	PHR → ATU	-0.224	-2.43	0.015	Supported

in which when PEU increases by 1, PU will increase by 0.653 standard deviations. Besides, H4 suggests that ATU positively and significantly influences BI, in which an increase of 1 in ATU leads to an increase in BI by 0.816 standard deviations. H5 and H6 prove that PENJ positively affects PU and ATU, respectively, where every 1-point increase in PENJ causes PU to increase by 0.595 standard deviations, and ATU to increase by 0.381 standard deviations. Meanwhile, H8 demonstrates that SE can exert a positive significant influence on PEU, and when SE increases by 1, PEU will increase by 0.773 standard deviations. Finally, PHR was discovered to have a significant negative influence on BI, where each unit increase in PHR leads to a 0.224 standard deviation decrease in ATU.

On the other hand, the analysis results for H1, H2, and H7 indicate that the three factors, PU, PEU, and SE, have some positive influence on ATU. However, this influence was not statistically significant. The results in Table 5 are represented in the path diagram, as displayed in Fig. 3.

The direction of the arrows signifies the direction of influence. Meanwhile, the number adjacent to the arrows represents the path coefficients. Bolded arrows represent significant results, whereas non-significant influences are represented by dashed arrows.

Discussion

This study investigates the factors that drive students' acceptance of the newly developed in-house mobile VR application, AsepticTech VR. Despite previous data suggesting the effectiveness of this application, students will not receive the intended benefit if they do not have the BI to use the application. Taken together, our study discovered that PENJ

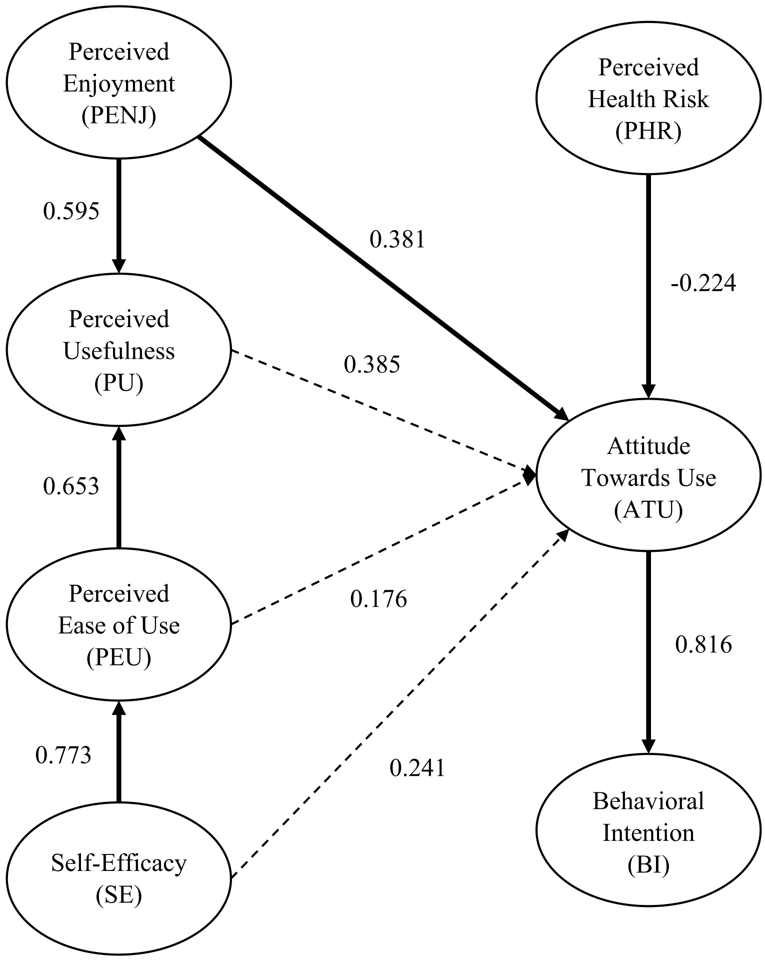

Fig. 3 Results of the path analysis represented in a path diagram

and PHR are two main factors that significantly influence the students' ATU regarding AsepticTech VR, which in turn significantly influences BI's use of the application.

The initial analysis suggested adequate validity and reliability for the TAM questionnaire used in this study. Item PHR1 was excluded due to its impact on the PHR construct, and its removal resulted in improved validity and reliability of PHR despite PEU suggesting a lower-than-recommended AVE. Furthermore, PEU exhibited issues with discriminant validity, as indicated in Table 3. However, the reliability of that construct was higher than the recommended value of 0.7 and was therefore deemed acceptable (Lam, 2012). Additionally, given the central role of PEU in driving BI according to the TAM model (Davis, 1988), the PEU construct was retained to ensure content validity. However, caution is required when interpreting PEU in later interpretations.

Results in Table 4 indicated that the most influential factor on BI is ATU, with a total standardized effect of 0.816. This is followed by PENJ, SE, PEU and PU. On the contrary, PHR has a negative effect on BI. The strong influence of ATU on BI was concurrent with that seen in the original TAM by Davis (1989). Contextually, this suggests that users' evaluation and appraisal of AsepticTech VR would play the most prominent role in determining the usage of the application. Interestingly, PENJ ranked first for its indirect effects and second in terms of its total effect on BI. This suggests that the PENJ associated with the use of the application is also another crucial factor in determining BI among users. This finding is rather encouraging, considering a Web-based Learning Technology (WBLT) survey given to another batch of students exhibited above-average ratings for the application's engagement dimension, as demonstrated in a prior work by the authors.

Since ATU is the most prominent determinant of BI, it would be feasible to identify factors that strongly influence ATU with the aim that these factors may be of emphasis during the future development of the application. Based on Fig. 2 and Table 5, two factors were determined to significantly influence ATU, namely PENJ and PHR.

First, the fact that PENJ positively and significantly influences ATU is an unsurprising result since H6 (PENJ significantly influences ATU) is a relationship consistently validated in previous works of literature (Fussell & Truong, 2022; Lee et al., 2019; Manis & Choi, 2019). The significant influence between PENJ and ATU is also a consistent result across extended reality technologies as well as entertainment technology, being a major driving force behind the attitude and usage intention of a particular technology (Park et al., 2014; Shin et al., 2017). As cited in a study by Jo and Park (2023), the positive emotional experience associated with technology, especially VR, serves as an intrinsic motivation that often transcends the practical functionality of the technology. In this study, this supported influence of PENJ on ATU reveals that an enjoyable experience provided by AsepticTech VR is a vital determinant that directly impacts the user's positive or negative evaluation of the application. This, ultimately, drives the intention to use AsepticTech VR. Therefore, as supported by its high total effects on BI, the enjoyment factor of AsepticTech VR and its ability to provide an overall learning experience is a major enabler of students' acceptance of this application.

Besides PENJ, PHR was also a significant determinant of ATU in this study. H9 (PHR significantly influences ATU) was also an expected connotation (Fussell & Truong, 2022; Koh et al., 2023; Sagnier et al., 2020). As provided in Table 5, the influence of PHR is inverse to ATU, which means that PHR negatively impacts ATU. Despite not being a large influence based on the path coefficient (-0.224), the influence was statistically significant. Such negative influence of PHR on ATU may also be explained by cybersickness reducing the presence in a virtual environment, negatively impacting the experience associated with the technology. Furthermore, another possible hypothesis not examined in this study is that cybersickness may negatively influence PENJ, which negatively affects user appraisal (Garrido et al., 2022). PHR is, therefore, an essential factor in minimizing users' experience since cybersickness represents an uncomfortable experience for the users and may deter usage. As cited in a systematic review by Tian et al. (2022), mitigation of cybersickness experience may be achieved by minimizing the influence of visual stimuli, eliminating cybersickness-triggering visual cues, and matching visually with vestibular stimuli.

Aside from the two main relationships discussed above, Table 5 provides four more significant relationships between the latent constructs. Unsurprisingly, two of the principal relationships postulated in the initial TAM model was supported in this study. Firstly, H3 (PEU significantly influences PU) was supported, consistent with the bulk of previous works of literature (Fussell & Truong, 2022; Majid & Shamsudin, 2019; Manis

& Choi, 2019; Maqableh et al., 2015; Sagnier et al., 2020). This suggests that the usefulness of AsepticTech VR can be significantly influenced by the application's design and how easy students perceive the application is to use. In addition, H4 (ATU significantly influences BI) was also supported, in line with existing studies (Fussell & Truong, 2022; Huang et al., 2023; Manis & Choi, 2019). Therefore, to increase students' intention to use AsepticTech VR, it is crucial to ensure that the application elicits characteristics deemed favorable by students. This includes an ability to provide an enjoyable but discomfort-free learning experience.

H5 (PENJ significantly influences PU) was also validated as expected, given that PENJ is a major predictor of PU (Abdullah & Ward, 2016). The significant relationship demonstrated an additional role of PENJ in encouraging the usage of AsepticTech VR. The associated enjoyment not only improves the user's overall appraisal of the application but also directly influences the users' perception of the usefulness of the application. Given the dual role of PENJ in improving user perception towards technology, and its high total effects on BI, it is therefore of utmost importance to ensure an overall enjoyable learning experience associated with using AsepticTech VR.

H8 (SE significantly influences PEU) was also not surprising since SE was the strongest predictor for PEU (Abdullah & Ward, 2016). Essentially, this suggests that the confidence the students have in their cell and tissue culture skills influences the ease of use and navigation within AsepticTech VR. Alternatively, this implies that users may find AsepticTech VR useful for practicing when they already have prior knowledge and confidence in their aseptic technique skillset.

Interestingly, two of the basic tenets of the original TAM model were not supported in this study. The first non-significant result, H1, suggested that PU did not significantly influence ATU. The reason behind this is unclear, as numerous studies support and validated the influence PU has on ATU (Cheung & Vogel, 2013; Fussell & Truong, 2022; Zheng & Li, 2020), though similar report as observed in this study has been made (Ibrahim et al., 2018). Despite this finding, descriptive statistics in Table 1 indicate that the PU construct attained a high mean score of $4.26 \pm (0.68)$, whereas users also reflected their ATU relatively positively with a mean score of $4.27 \pm (0.78)$. These two findings indicate that students still find AsepticTech VR useful and positively appraise the application. However, the PU did not significantly influence users' judgement towards the application.

Secondly, H2, which postulates an influence by PEU on ATU, was also not supported. In other words, the PEU was discovered to not significantly influence user attitude towards the application. This finding was supported by Lee et al. (2019). As cited in their study, this situation may occur partly due to users not recognizing the difficulties associated with operating in the VR environment. This is particularly relevant in this study, especially since AsepticTech VR operates on a gazed-based system where interaction with the virtual environment is conducted solely via head movement. According to the KANO model, when such ease of use is perceived as a mandatory attribute of VR, any dissatisfaction among the user towards the application can deteriorate rapidly. This results in PEU not being able to significantly affect ATU altogether. Another possible explanation was quoted by Sagnier et al. (2020), stating that a larger sample size could be required to have enough power to test the significance of the PEU-ATU relationship due to the relatively unstable nature of this construct. Moreover, as cited by Barrett et al. (2021), the lack of influence on BI by PEU could be due to the users' belief that new technologies gradually become easier as their familiarity with the technology increases. Additionally, SE was not discovered to significantly influence ATU. This finding has been reported previously (Fussell & Truong, 2022; Park, 2009). Specifically, (Fussell and Truong (2022) demonstrated that SE has a negative but non-significant result on ATU. However, contrasting results have also been proven (Koh et al., 2023), and generally, the result was inconsistent. A possible speculation is that the confidence level towards their cell culture skills was not considered when students appraised the technology since AsepticTech VR was developed to enable them to learn and practice these skill sets.

Overall, the present study provided a student-centric view of the critical factors that may encourage the usage of technology-aided practical learning in the context of cell and tissue culture aseptic techniques. In this study, PENJ and PHR are the two factors significantly influencing ATU, even more so than traditional determinants like PU and PEU. Due to the strongly contrasting findings as compared to conventional TAM models, these findings suggest that determinants of users' appraisal and intention to use may be context-dependent and differ based on the purpose of a particular technology (Fussell & Truong, 2022). Furthermore, as one of the pioneer studies that examined the factors influencing acceptance of bioscience practical learning technologies, the findings from these results may help steer the overall direction of similar learning tools.

Besides the practical contributions, this study also provided some theoretical implications with regard to the study of technology acceptance. Firstly, this study narrowed down the TAM model into the selected seven constructs with proven validity and reliability, which may be useful when performing similar studies with a smaller sample size. In addition, given the rigor of the model, future studies with a similar context may consider applying or expanding the TAM used in this study to investigate factors that influence the acceptance of bioscience students on related learning technology. Finally, this study also provided a rare example of a case where PU was not discovered to be significantly influential on ATU despite a long-standing and established interrelationship between the two constructs. Nevertheless, further investigations may be required to elucidate this observed phenomenon.

However, the implications and contributions mentioned above should be considered, considering the limitations of the following study. One limitation in our study stems from the sample population of biomedical undergraduates taking the course SBP3410 Cell and Tissue Culture at Universiti Putra Malaysia, which contains only around 60 students per session. Two problems arise from this constraint. Firstly, the demographic of the sample population is highly homogenous in terms of age and educational background. On top of that, the small sample size used in this study ($N = 55$) may pose a problem as the statistical analysis results may not be generalizable to a larger population, such as all biomedical undergraduates within the country. However, this does not indicate that the study lacks validity, given that the application was indeed given access to its intended target population, and the findings theoretically reflect the perception of the said population about AsepticTech VR. Nevertheless, future studies may consider recruiting a bigger sample size, including a sample population with a more diverse background, such as post-graduate students and educators in relevant fields, to obtain a more consensus view on the attributes of the application.

In conclusion, PENJ and PHR are the principal factors that significantly influence ATU in the context of AsepticTech VR usage, further increasing users' BI to use said application. AsepticTech VR, therefore, stands out to the users as a fun and attractive method to engage students in learning about cell and tissue culture aseptic techniques. It is also PU and PEU by the users, though these perceptions are not a significant determinant in influencing their appraisal of AsepticTech VR. Taken together, our study suggests that AsepticTech VR is well accepted by the students, and therefore encourage the incorporation of this application in the teaching and learning activities of cell and tissue culture courses among biosciences undergraduates.

Abbreviations

TAM	Technology Acceptance Model
PU	Perceived Usefulness
PEU	Perceived Ease of Use
ATU	Attitude Towards Use
BI	Behavioral Intention
PENJ	Perceived Enjoyment
PHR	Perceived Health Risk
SE	Self-Efficacy
CFA	Confirmatory Factor Analysis
AVE	Average Variance Extracted
CR	Composite Reliability

Acknowledgements
Not applicable.

Authors' contributions
CLT conceived the idea and designed the content of the AsepticTech VR application. HHH and MSC reviewed the content of the AsepticTech VR application. SHL and SPS developed the AsepticTech VR application. CLT planned the cross-sectional study. CLT, KYL, and CWL conducted the cross-sectional study. MSC assembled the questionnaire. CLT and HHH reviewed the questionnaire before their use in the study. CWL and HIS analysed the study results. CWL and CLT took the lead in writing the manuscript. All authors collectively reviewed the manuscript.

Funding
This study was supported by the*Geran Insentif Penyelidikan untuk Pengajaran dan Pembelajaran(GIPP) grant of Universiti Putra Malaysia [grant number 9323768]*.

Availability of data and materials
The data collected is available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate
All procedures within the study were conducted in accordance with the ethical standards as stated in the 1964 Declaration of Helsinki. This study obtained ethical clearance from the Ethic Committee for Research involving Human Subjects Universiti Putra Malaysia (JKEUPM) under the code JKEUPM-2022–462.

Informed consent
The participants were informed about the aim of study, the study design, and potential benefits and risks associated with the study. The planned use of data was also disclosed, as highlighted in Section Methodology: Participants. Informed consent was obtained from the study participants prior to their recruitment.

Competing interests
CLT and HHH are educators for the course SBP3410 Cell and Tissue Culture taken by the subject population. To address potential conflicts of interest, students were briefed that their participation in this study is voluntary and that the responses provided will not affect their scores in SBP3410.

Received: 12 October 2023 Accepted: 26 April 2024
Published online: 07 June 2024

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