Lentera Pendidikan : Jurnal Ilmu Tarbiyah dan Keguruan
Vol. 27, No. 1, June 2024, pp. 47-62
ISSN: 2354-9629 (Print) 2549-1334 (Online)
Doi: https://doi.org/10.24252/lp.2024v27n1i4

INVESTIGATING UNIVERSITY STUDENT'S ACCEPTANCE OF VIRTUAL AND REMOTE LABS IN THEIR LEARNING

Nanda Eska Anugrah Nasution[1], Chairany Rizka[2]
[1,2]UIN Kiai Haji Achmad Siddiq Jember, Indonesia
[1,2]Mataram Street No. 1, Karang Miuwo, Mangli, East Java, Indonesia
Email: nsteska@gmail.com[1], rizkachairany@gmail.com[2]

Received May 10, 2023; Revised December 14, 2023; Accepted May 19, 2024

Abstract:

Virtual and remote laboratories have become supplementary or extra tools for hands-on biology laboratories. In this study, we modified the technology acceptance model to incorporate three additional external variables derived from flow theory in predicting students' acceptance and use of virtual and remote laboratories. This research included 145 college students. These students used virtual and remote laboratories for at least three months. The learning subjects in this research are deoxyribonucleic acid extraction, polymerase chain reaction, gel electrophoresis, deoxyribonucleic acid microarray, and flow cytometry. Using SPSS 25.0, a multiple regression analysis was performed to test the structural model hypothesis. This study validated the association between the basic variables used in the technology acceptance model: perceived ease of use, perceived usefulness, attitudes toward using, behavioral intention, and actual use. There were no surprising discoveries for the technology acceptance model's primary variables. Concentration and perceived enjoyment in the flow theory variables have an extensive relationship with the technology acceptance model variables, perceived usefulness, and perceived ease of use. Meanwhile, one flow theory variable, time distortion, exhibits no significant relationship with perceived usefulness or ease of use.

Abstrak:

Laboratorium virtual dan jarak jauh menjadi tren yang dimanfaatkan sebagai alat bantu praktikum biologi. Penelitian ini memodifikasi model penerimaan teknologi dalam penelitian ini dengan memasukkan tiga variabel eksternal tambahan yang berasal dari teori *flow* dalam memprediksi bagaimana mahasiswa menerima dan menggunakan laboratorium virtual dan jarak jauh. Penelitian melibatkan 145 mahasiswa. Para mahasiswa ini telah menggunakan laboratorium virtual dan jarak jauh setidaknya tiga bulan. Materi pembelajaran penelitian ini adalah ekstraksi asam deoksiribonukleat (DNA), *polymerase chain reaction* (PCR), *gel electrophoresis*, *deoxyribonucleic acid microarray*, dan *flow cytometry*. Hubungan antara variabel dasar yang digunakan dalam *technology acceptance model* yaitu kemudahan penggunaan yang dirasakan, kebergunaan yang dirasakan, sikap, niat perilaku, dan penggunaan sebenarnya divalidasi dalam penelitian ini. Data yang terkumpul dianalisis regresi berganda dengan bantuan SPSS 25. Tidak ada penemuan mengejutkan untuk variabel utama *technology acceptance model*. Variabel konsentrasi dan kesenangan yang dirasakan pada teori *flow* memiliki hubungan yang signifikan dengan variabel *technology acceptance model*, kebergunaan yang dirasakan dan kemudahan penggunaan yang dirasakan. Sedangkan satu variabel teori *flow*, distorsi waktu tidak menunjukkan hubungan yang signifikan dengan kebergunaan yang dirasakan atau kemudahan penggunaan yang dirasakan.

Keywords:
Flow theory, Pre-Service Teachers, Technology Acceptance Model, University Student, Virtual and Remote Laboratories

How to Cite: Nasution, N. E. A. & Rizka, C. (2024). Investigating University Student's Acceptance of Virtual and Remote Labs in their Learning. *Lentera Pendidikan : Jurnal Ilmu Tarbiyah dan Keguruan,* 27(1), 47-62. https://doi.org/10.24252/lp.2024v27n1i4.

INTRODUCTION

Laboratories are an essential part of biology education and the accomplishment of its aims. It is important to give students practical opportunities to perform scientific experiments. The earliest and most popular method of laboratory education is hands-on or physical laboratories (Abdulwahed & Nagy, 2009). However, hands-on labs present a series of limitations, especially during the COVID-19 pandemic situation, such as: (1) It requires students to physically present in the lab; (2) Some materials, resources, and apparatus that should be supplied in these laboratories are expensive (Ambuisaidi, Musawi, Al-Balushi, 2018); (3) Students encounter difficulties while engaging in discussions and self-reflection when they are heavily focused on the mechanical, technical, and procedural aspects of the practical laboratory (Gunstone, 1991); (4) Some hands-on laboratories experiment requires students to answer problems that are more complex than the student's cognitive capacity, which is limited by the short amount of time the laboratory typically provides (Kirschner, 1988); and (5) Just a certain range of experiments and experimental exercises can be carried out with limited resources during the time available (Ambuisaidi, Musawi, & Balushi, 2018).

The emergence of artificial intelligence (Nasution, 2023), virtual reality (Freina & Ott, 2015), augmented reality, and other interactive multimedia, as well as Hasanah, Farihah, & Nasution (2022), are examples of the rapid growth of technology and information. Virtual and remote laboratories have arisen as complementary or additional resources for hands-on biology laboratories (Abdulwahed & Nagy, 2009) and provide answers to hands-on lab limitations. A virtual and remote laboratory (VRL) is an interactive environment designed to create and perform simulated experiments without real laboratory tools and materials (Babateen, 2011). Nowadays, a variety of virtual and remote laboratories have been developed successfully (Makransky, Terkildsen, & Mayer, 2019; Syahfitri, Manurung, & Sudibyo, 2019; Pramono, Prajanti, & Wibawanto, 2019; Birt, Stromberga, & Cowling, 2018; Moro, Stromberga, & Stirling, 2017; Chao, Chiu, DeJaegher, 2016).

There is a range of benefits to virtual and remote laboratories (VRL) compared to hands-on labs, such as they are more cost-effective to incorporate and run, secure, safe, and not limited by space or time (Abdulwahed & Nagy, 2009). Moreover, VRL allows students to become more involved in their biology experiments and it provides students with opportunities to quickly create and comprehend difficult topics and encourages students to replicate demonstrations that they do not understand or as an exam review (Falode, 2018). VRL provides students with expertise in the preparation and analysis of experiment results, engaging in the team, operating a microscope or any lab equipment, and the practice of all other functional and collaboration skills appropriate for scientific performance (Ambuisaidi, Musawi, & Balushi, 2018). Previous empirical studies validated that the learning achievement of students using VRL is equivalent to or greater than the learning achievement of students using actual experiments (Tatli & Ayas, 2013; Hawkins & Phelps, 2013; Barbeau, Johnson, & Gibson, 2013; Pyatt & Sims, 2012; Lang, 2012; Koretsky, Kelly, & Gummer, 2011; Tuysuz, 2010; Sun, Lin, & Yu, 2008).

New technology innovations such as VRL may be ineffective when they are not approved or refused by the end consumers, students (Al-Assaf, Almarabeh, & Eddin, 2015). Therefore, a study to explain what factors are determining University Students such as pre-service teachers' uptake of virtual and remote laboratories for academic purposes is crucial, to help foresee their pedagogical use of VRL in future teaching and learning activities. Understanding the advantages of Virtual Reality Learning (VRL) can enable teachers to develop more sophisticated learning strategies. This is important since effective learning planning plays a critical role in determining the success of the learning process (Romdaniyah, Nasution, & Rizka, 2023). Among these models, TAM is the best-known and suited model and has been empirically validated to forecast student acceptance and the usage of several online learning technology platforms as an innovative and competent instrument (Zain, Hanafi, & Don, 2019; Teo, Zhou, & Fan, 2019; Al-Assaf, Almarabeh, & Eddin, 2015; Alharbi & Drew, 2014; Rauniar, Rawski, & Yang, 2014; Moon & Kim, 2001).

To date, a broad variety of technology acceptance theories have been documented in observational studies carried out based on technology acceptability, such as the Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975), the Expectation Confirmation Model (ECM) (Bhattacherjee, 2001), several MIS models, and the Technology Acceptance Model (TAM) (Davis, 1989). Among these models, TAM is the well-established and most applicable model and has been empirically checked as an accurate and capable model to estimate student acceptance of and usage of online learning programs (Zain, Hanafi, & Don, 2019; Teo, Zhou, Fan, & Huang, 2019; Al-Assaf, Almarabeh, & Eddin, 2015; Alharbi & Drew, 2014; Rauniar, Rawski, & Yang, 2014). TAM contains perceived usefulness (PU) and perceived ease of use (PEU) as two key elements in the student approach to the usage of technology (Davis, 1989). Following TAM, additional variables were introduced to the model to form an expanded TAM. In this study, we extended the TAM to include three additional external variables adopted from flow theory (Csikszentmihalyi, 1997). According to Zhang & Wang (2022), Mahfouz, Joonas, & Opara (2020) and Csikszentmihalyi (1997), flow theory describes a situation in which people engage in an activity if everything else is irrelevant. Playing video games, browsing the internet, or using social media are a few examples of such situations. The three additional external variables are concentration, time distortion, and perceived enjoyment.

THEORETICAL BACKGROUND AND HYPOTHESES

Technology Acceptance Model (TAM)

Davis introduced TAM (1989) as a model for understanding the user adoption of emerging technologies. Davis (1985) developed the technology acceptance model (TAM) based on the principle of reasoned action to establish a further universal theoretical framework for conscientious behavior (Nasution, 2023; Liao, Hong, & Wen, 2018). TAM is probably the most commonly used theoretical model of technology studies (Essel & Wilson, 2017). TAM considers the key factors for technology adoption to be two basic values: perceived usefulness (PU) and perceived ease of use (PEU). PU is the degree to which the student believes that utilizing a particular system will boost his learning output, and PEU is the degree to which the student finds it free of effort to use a specific system (Davis, 1989). In TAM, PEU directly affected PU. PU and PEU directly influence attitudes toward using (ATU) technology. In certain cases, student ATU may have a strong impact on their behavior (Compeau & Higgins, 1995).

TAM proposed that both ATU and PU are the strongest factors that affect behavioral intention (BI) (Teo, Zhou, & Fan, 2019; Almarabeh, Mohammad, & Yousef, 2014). Moakofhi, Phiri, & Leteane (2019) explained that BI is the degree to which a prospective student has devised prearranged arrangements to conduct any defined future action. Finally, BI describes the actual use (AU) of a given technological framework and thus establishes the adoption of the technology (Alharbi & Drew, 2014). Yasa, Ratnaningrum, & Sukaatmaja (2014) defines the AU as the real adoption of a technology that can be detected through the sum of the technology's commonness and timing. As a result, the number of AU students in this study is determined by adding up the time students spend using VRL. Hence, the following hypothesis is proposed:

H1: The Perceived ease of use affects positively perceived usefulness of VRL.
H2: The Perceived ease of use affects positively attitude towards using VRL.
H3: The Perceived usefulness affects positively attitude towards using VRL.
H4: The Perceived usefulness affects positively behavioral intention to use VRL.
H5: Attitude towards using affects positively behavioral intention to use VRL.
H6: Behavioral intention to use affects positively actual using VRL.

Flow Theory

Csikszentmihalyi (1997) described flow experience as the comprehensive experience that individuals develop when they act with complete participation. While individuals are in flow mode, they get immersed in their behaviors and cannot perceive shifts in their environment. In short, they neglect self-consciousness, focusing instead on their ongoing tasks (M. C. Lee, 2010). Csikszentmihalyi (2014) subsequently described nine flow components: goals are clear, feedback is immediate, skills match challenges, concentration is deep, problems are forgotten, control is possible, self-consciousness disappears, the sense of time is altered, and the experience becomes autotelic. Many researchers generally did not follow all of these nine factors because of several factors, such as the specific emphasis and extent of a study; it may not require a comprehensive analysis of all nine components; evaluating all nine components fully can be a time-consuming and resource-intensive process; or various contexts and domains may prioritize specific components while downplaying others (Buil, Catalán, & Martínez, 2018; Zhang & Wang, 2022). Instead, many researchers chose or adjusted unique constructs to assess flow depending on the context and intent of their study.

Flow is a complex theory that scholars often evaluate in several other components. Li & Browne (2006) assessed flow using four elements: focused attention, control, curiosity, and temporal dissociation. Lee (2010), Ghani, Supnick, & Rooney (1991), Koufaris (2002) proposed two-dimensional flow perceptions: perceived enjoyment and concentration. Chang, Warden, & Liang (2018) examined students' flow experiences with engagement, enjoyment, and control. Zhang & Wang (2022) defined two flow components: time distortion and focused attention. In this current study, we adopted concentration, time distortion, and perceived enjoyment as constructs to investigate pre-service teachers' flow experiences in VRL usage.

H7: The concentration affects positively perceived ease of use of VRL.

H8: The time distortion affects positively perceived ease of use of VRL.

H9: The perceived enjoyment affects positively perceived ease of use of VRL.

H10: The concentration affects positively perceived usefulness of VRL.

H11: The time distortion affects positively perceived usefulness of VRL.

H12: The perceived enjoyment affects positively perceived usefulness of VRL.

RESEARCH METHOD

Participants

The participants were pre-service teachers trained at biology education departments in Indonesia during the academic year 2020–2021. Pre-service teachers were selected based on their high likelihood of future utilization of virtual and remote labs. It is because of their ongoing learning and teaching of various biological concepts that constrain practical experimentation for their students. The pre-service teachers are designed to serve in secondary and high schools post-graduation. All participants had the requisite computer skills. Participants were informed their engagement was optional, their score would not be impacted, and their responses would stay entirely private and secret to prevent any bias. Table 1 shows the demographics of the sample.

The experiment was performed for eight sessions, with three hours per session and one session per week. Learners were requested to complete a virtual experiment with a specific subject in every session. All the pre-service teachers answered the questionnaire at the end of the experiment in session eight. The learning subjects in this research are DNA extraction, PCR, gel electrophoresis, DNA microarray, and flow cytometry.

Table 1. Descriptive statistics of respondents' characteristics

Measure	Items	Frequency	Percent
Gender	Female	119	82.07
	Male	26	17.93
Age	18	2	1.37
	19	52	35.86
	20	72	49.66
	21	17	11.72
	22	2	1.37
Family background	Rural area	107	73.79
	Urban area	38	26.2

Questionnaire Development

A two-section questionnaire was developed to understand pre-service teachers acceptance of and plans to continue using VRL in their future teaching. The first section of the questionnaire contained questions concerning the demographic details of learners, such as age and gender (Moakofhi, Phiri, & Leteane, 2019; Alharbi & Drew, 2014). The second section of the questionnaire contains 24 items: 4 for PU, four for PEU, three for AT, three items for BI, two for AU, three for C, three for PE, and two for TD. Two lecturers who are education experts reviewed and validated the questionnaire, as done by Moakofhi, Phiri, & Leteane (2019)To assess these questionnaire items, we implemented a five-point Likert scale (5 = strongly agree/frequently, 4 = agree/often, 3 = average/occasionally, 2 = disagree/rarely, and 1 = strongly disagree/never). The Cronbach's alpha was measured to be .935. It confirms that all test components are highly reliable.

Table 2. Descriptive statistics and Cronbach alpha coefficient value

Variable	Item	Mean	SD	Variance	Min	Max	Alpha
Perceived ease of use	PEU1	3.07	.918	.842	1	5	.758
	PEU2	3.4	.767	.589	1	5	
	PEU3	2.99	.858	.736	1	5	
	PEU4	3.42	.77	.593	1	5	
Perceived usefulness	PU1	3.46	.746	.556	1	5	.805
	PU2	3.88	.983	.965	1	5	
	PU3	3.48	.746	.557	1	5	
	PU4	3.82	.969	.94	1	5	
Attitudes toward using	AT1	3.37	.789	.622	1	5	.764
	AT2	3.75	.932	.868	1	5	
	AT3	3.48	.809	.654	1	5	
Behavioral intention	BI1	3.8	.955	.911	1	5	.81
	BI2	3.44	.716	.512	1	5	
	BI3	3.83	.905	.82	1	5	

Actual use	AU1	3.77	.896	.802	1	5	.795
	AU2	3.86	.910	.828	1	5	
Concentration	C1	3.01	.920	.847	1	5	.857
	C2	3.06	.911	.83	1	5	
	C3	3.03	.866	.749	1	5	
Time Distortion	TD1	3.39	.556	.31	1	5	.85
	TD2	3.45	.564	.318	1	5	
Perceived Enjoyment	PE1	3.01	.858	.736	1	5	.588
	PE2	3.83	1	1	1	5	
	PE3	3.64	.926	.857	1	5	
Total	24 items	3.47					.935

RESULTS AND DISCUSSION

Results

Table 3. Numbers of items, mean, SD, and correlation of all variables

Variable	Mean	SD	PEU	PU	AT	BI	AU	C	TD	PE
PEU	3.21	.63	1							
PU	3.66	.69	.595**	1						
AT	3.53	.69	.644**	.845**	1					
BI	3.69	.73	.496**	.836**	.765**	1				
AU	3.81	.82	.378**	.801**	.75**	.805**	1			
C	2.03	.79	.802**	.327**	.402**	.225**	.069	1		
TD	3.42	.42	.075	.079	.046	-.023	.033	.097	1	
PE	2.49	.68	.675**	.822**	.818**	.706**	.687**	.512**	.033	1

The path significance of every hypothesized correlation in the research model and the coefficients of determination (R2 value) for every path are tested. The standardized path coefficients and path significances are shown in Table 3, Table 4, and Fig. 1. All twelve hypothesized correlations were highly significant at $p < 0.05$, except for the two relations between TD and PEU and TD and PU. The findings have shown that the effect of both PEU on PU ($\beta = 0.649$, $p < 0.001$) and the effect of PEU on AT ($\beta = 0.708$, $p < 0.001$) was significant, thus supporting H1 and H2. H3 and H4 were supported since PU had a positive impact on both AT ($\beta = 0.852$, $p < 0.001$) and BI ($\beta = 0.892$, $p < 0.001$).

Table 4. Regression results for model hypotheses

Independent Variable	β	SE of β	t	P	R^2	Dependent Variable
PEU	.649	.073	8.856	.000	.354	PU
PEU	.708	.07	10.077	.000	.415	AT
PU	.852	.045	18.933	.000	.715	AT
PU	.892	.049	18.228	.000	.699	BI
AT	.81	.057	14.197	.000	.585	BI
BI	.899	.055	16.22	.000	.648	AU

C	.64	.04	16.04	.000	.643	PEU
TD	.112	.125	0.899	.37	.006	PEU
PE	.62	.057	10.937	.000	.455	PEU
C	.284	.069	4.136	.000	.107	PU
TD	.129	.136	.953	.342	.006	PU
PE	.824	.048	17.229	.000	.675	PU

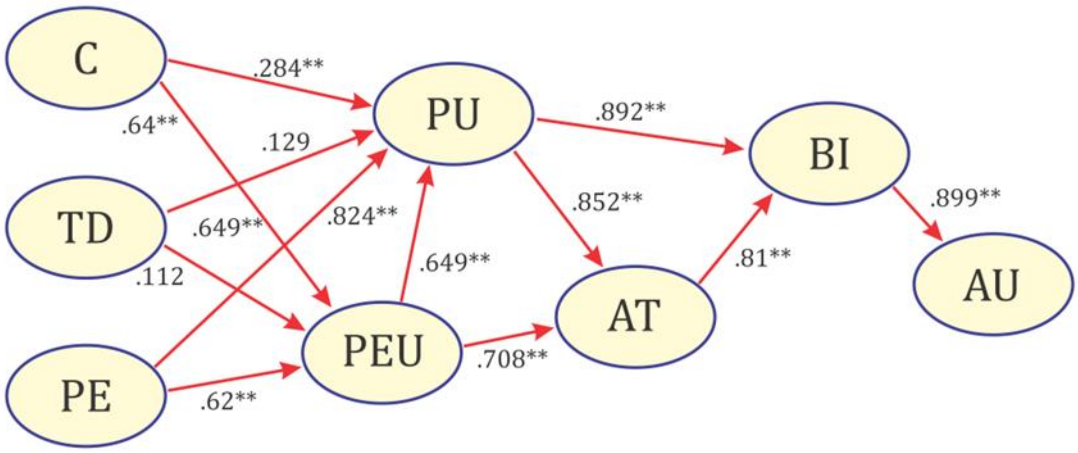

Figure 1. Results of testing the structural model (* p<0.05; ** p<0.001)

The findings revealed that there was an effect of AT on BI ($\beta = 0.81$, $p < 0.001$) and the effect of BI on AU ($\beta = 0.899$, $p < 0.001$) that was significant, so H5 and H6 were supported. Based on these results, all existing relationships in the original TAM are significant.

The impact of the external construct C on PEU ($\beta = 0.64$, $p < 0.001$) and PU ($\beta = 0.284$, $p < 0.001$) was significant, H7 and H10 were supported. The impact of another external construct, TD, on PEU ($\beta = 0.112$, $p > 0.05$) and PU ($\beta = 0.129$, $p > 0.05$) was insignificant, H8 and H11 were not supported. The impact of the last external construct, PE, on PEU ($\beta = 0.62$, $p < 0.001$) and PU ($\beta = 0.824$, $p < 0.001$) was significant, therefore H9 and H12 were supported.

Discussion

The key purpose of the present research was to examine the suitability of the extended TAM as a model to describe the continued intent to use VRL in future science classroom teaching and learning between Indonesian pre-service teachers. The outcomes of this study are consistent with the original TAM findings (Davis, Bagozzi, & Warshaw, 1992), and all the initial TAM-based hypotheses in this report have shown positive, statistically significant correlations. The findings confirmed a positive direct impact of PEU on PU, consistent with the previously conducted research (Zhao & Wang, 2020; Rai & Selnes, 2019; Teo, Zhou, & Fan, 2019; Teo, Sang, & Mei, 2018; Alharbi & Drew, 2014; Teo, 2010; Chang, Yan, & Tseng, 2012; Liu, Chen, & Sun, 2010; Lee, 2010; Liu, Liao, & Pratt, 2009). This result shows that as PEU increases, so does PU. This experiment also revealed that PEU has a significant effect on AT, adhering to previous research (Ziraba, Akwene, & Nkea, 2020; Teo, Zhou, & Fan, 2019; Zain, Hanafi, & Don, 2019; Adwan & Smedley, 2013; Lee, 2010; Liu, Liao, & Pratt, 2009). This study shows that PU has a significant effect on AT; this relates to prior reports (Zhao & Wang, 2020; Teo, Zhou, & Fan, 2019; Lee, 2010; Liu, Liao, & Prett, 2009). Thus, when students perceived VRL as easy to use and/or useful, they were more inclined to believe in its potential. In contrast to previous studies that mostly looked into the adoption of other emerging technologies in education, this study explicitly examines the use of virtual and remote laboratories. This research shows a significant positive relationship between AT and BI and between PU and BI; this result reflects previous studies (Zhao & Wang, 2020; Teo, Zhou, & Fan, 2019; Almarabeh, Mohammad, & Yousef, 2014; Adwan & Smedley, 2013; Lee, 2010; Liu, Liao, & Prett, 2009). Thus, if a student has a higher PU and AT of the VRL system, he or she would be more likely to utilize the VRL. A strong positive correlation between BI and AU was established as predicted, which is compatible with the findings of previous studies (Dumpit & Fernandez, 2017; Fathema, Shannon, & Ross, 2015). These findings indicate that when pre-service teachers have positive BI, they are expected to also use VRLs.

In this study, there are three external variables based on flow theory, and one of them is C. For students to be in a state of flow, they must first focus on the tasks at hand (Koufaris, 2002), which in this study is using the VRL system. The findings of this study indicate that there is a significant positive correlation between C and PU and C and PEU. This finding suggests that if a student has a high C using the VRL system, he or she is more likely to have higher PU and PEU levels. The relationship between C and PU, as well as C and PEU, has not been extensively investigated. Prior research, however, indicated a significant relationship between concentration and the willingness of learners to continue using technology (continuance) (M. C. Lee, 2010). Students who concentrate while using the VRL system will find it easier to obtain a flow experience (M. C. Lee, 2010). Using the VRL system requires students' undivided attention, particularly when reviewing the fundamental theories of an experiment. The students then conduct the virtual experiment, which, if designed thoughtfully and attractively, will compel them to pay close attention. Students who concentrate on using technology will filter out irrelevant perceptions and thoughts so that the focus is solely on the technology's use (Moon & Kim, 2001). When students concentrate on learning, in this case when using the VRL system, they will lose awareness of everything except what they are learning; this state is known as flow (Csikszentmihalyi, 1997).

This study used the flow theory variable TD as an external TAM variable. The findings showed no significant correlation between TD and PU or TD and PEU. Although previous research (Esteban-Millat, Martínez-López, & Huertas-García, 2014) indicated a correlation between TD and students' attitudes toward technology, this study argued that there is no correlation between TD and PU, and PEU toward the VRL system. Similar to the findings of Zhang & Wang (2022), this study found no significant relationship between TD and PU and the intention to continue using technology. This suggests that students do not perceive TD as a point affecting PU and PEU as measured using the VRL system.

PE is the flow theory variable used as an external variable for TAM in this investigation. Following previous research (Davis, Bagozzi, & Warshaw, 1992; Moon & Kim, 2001), the results of this study indicate a significant positive relationship between PE and PU, as well as between PE and PEU. This finding suggests that if a student has a high PE toward the VRL system, he is most likely to have higher PU and PEU levels. According to Lee's (2010) research, pupils' attitudes toward the utilization of new technology vary. Students who use technology such as the VRL system want to appreciate using it, thereby putting them in a state of flow (Lee, Cheung, & Chen, 2005). When students find the VRL system enjoyable, they are engaged in an activity they enjoy and do not require external motivation, such as punishment or reward, to do so.

According to the findings of previous researchers, technology in education offers a variety of entertaining functions for students, so they will enjoy it and can be more focused using technology. Lee (2010) believes the VRL system potentially improves the learner experience. This study found that when students experience flow in using educational technology, in this case, P.E. and C., they are more likely to embrace and utilize that technology in the future.

CONCLUSION

In this study, we have combined TAM and flow theory to explain how students adopt VRL technology. The TAM model uses three flow theory variables as external variables: C, TD, and PE. This study aims to contribute to a better understanding of VRL adoption and general student use. This study validated the relationship between the fundamental TAM variables (PEU, PU, AT, BI, and AU). There were no surprising discoveries for the TAM primary variables. C and PE in the flow theory variables have a notable relationship with the TAM variables, PU and PEU. In the meantime, one flow theory variable, TD, exhibits no significant relationship with PU or PEU.

Limitations constrained this research, such as the exclusive reliance on respondents from a single university. This is because of the researchers' access to funding for studies conducted at other universities. Further studies may be conducted to analyze TAM by expanding and/or modifying the model through the addition of external variables, a different sample of students, and/or different VRL usage conditions. We recommend examining the effectiveness of VRL on several 21st-century competencies, such as creativity and critical thinking abilities or science process skills (Harahap, Nasution, & Manurung, 2019), using quasi-experimental methods.

REFERENCES

Abdulwahed, M., & Nagy, Z. K. (2009). The Impact of the Virtual Laboratory on the Hands-on Laboratory Learning Outcomes, a Two Years' Empirical Study. *20th Australasian Association for Engineering Education Conference*.

Adwan, A. A., & Smedley, J. (2013). Exploring Students Acceptance of E-Learning Using Technology Acceptance Model in Jordanian Universities. *International Journal of Education and Development Using Information and Communication Technology*, *9*(2), 4–18. https://files.eric.ed.gov/fulltext/EJ1071365.pdf.

Al-Assaf, N., Almarabeh, T., & Eddin, L. (2015). A Study on the Impact of Learning Management System on Students of the University of Jordan. *Journal of Sosftware Engineering and Applications*, *8*(590–601). https://doi.org/10.4236/jsea.2015.811056.

Alharbi, S., & Drew, S. (2014). Using the Technology Acceptance Model in Understanding Academics' Behavioural Intention to use Learning Management Systems. *International Journal of Advanced Computer Science and Applications*, *5*(1), 143–155. https://doi.org/10.14569/IJACSA.2014.050120.

Almarabeh, T., Mohammad, H., Yousef., & Majdalawi, Y, K. (2014). The University of Jordan E-Learning Platform: State, Students' Acceptance and Challenges. *Journal of Software Engineering and Applications*, *999–1007*. https://doi.org/10.4236/jsea.2014.712087.

Ambuisaidi, A., Musawi, A. A., Al-Balushi, S., & Al-Balushi, K. (2018). The Impact of Virtual Lab Learning Experiences on 9th Grade Students' Achievement and Their Attitudes Towards Science and Learning by Virtual Lab. *Journal of Turkish Science Education*, *15*(2), 13–29. https://doi.org/10.12973/tused.10227a.

Babateen, H. M. (2011). *The Role of Virtual Laboratories in Science Education*. IACSIT Press.

Barbeau, M. L., Johnson, M., Gibson, C., & Rogers, K. A. (2013). The Development and Assessment of an Online Microscopic Anatomy Laboratory Course. *Anatomical Sciences Education*, *6*(4), 246–256. https://doi.org/10.1002/ase.1347.

Bhattacherjee, A. (2001). Understanding Information Systems Continuance: An Expectation-confirmation model. *MIS Quarterly*, *25*(3), 351–370. https://doi.org/10.2307/3250921.

Birt, J., Stromberga, Z., Cowling, M., & Moro, C. (2018). Mobile Mixed Reality for Experiential Learning and Simulation in Medical and Health Sciences Education. *Information (Switzerland)*, *9*(2), 1–14. https://doi.org/10.3390/info9020031.

Buil, I., Catalán, S., & Martínez, E. (2018). Exploring Students' Flow Experiences in Business Simulation Games. *Journal of Computer Assisted Learning*, *34*(2), 183–192. https://doi.org/10.1111/jcal.12237.

C, T. (2010). The Effect of the Virtual Laboratory on Students' Achievement and Attitude in Chemistry. *International Online Journal of Educational Sciences*, *2*(1), 37–53. https://iojes.net/?mod=tammetin&makaleadi=&makaleurl=IOJES_167.pdf&key=41381.

Chang, C. C., Warden, C. A., Liang, C., & Lin, G. Y. (2018). Effects of Digital Game-based Learning on Achievement, Flow and Overall Cognitive Load. *Australasian Journal of Educational Technology*, *34*(4), 155–167. https://doi.org/10.14742/ajet.2961.

Chang, C. C., Yan, C. F., & Tseng, J. S. (2012). Perceived Convenience in an Extended Technology Acceptance Model: Mobile Technology and English Learning for College Students. *Australasian Journal of Educational Technology*, *28*, 809–826. https://doi.org/10.14742/ajet.818.

Chao, J., Chiu, J. L., DeJaegher, C. J., & Pan, E. A. (2016). Sensor-Augmented Virtual Labs: Using Physical Interactions with Science Simulations to Promote Understanding of Gas Behavior. *Journal of Science Education and Technology*, *25*(1), 16–33. https://doi.org/10.1007/s10956-015-9574-4.

Compeau, D. R., & Higgins, C. A. (1995). Computer Self-efficacy: Development of a Measure and Initial Test. *M.I.S. Quarterly*, *19*(2). https://doi.org/10.2307/249688.

Csikszentmihalyi, M. (1997). *Finding Flow: The Psychology of Engagement with Everyday Life*. Basic Books.

Csikszentmihalyi, M. (2014). *Applications of Flow in Human Development and Education: The Collected Work of Mihaly Csikszentmihalyi*. Springer.

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, *13*(3), 319–340. https://doi.org/10.2307/249008.

Davis, F. D., Bagozzi, R. ., & Warshaw, P. R. (1992). Extrinsic and Intrinsic Motivation to Use Computers in the Workplace. *Journal of Applied Social Psychology*, *22*. https://doi.org/10.1111/j.1559-1816.1992.tb00945.x.

Dumpit, D. Z., & Fernandez, C. J. (2017). Analysis of the Use of Social Media in Higher Education Institutions (HEIs) Using the Technology Acceptance Model. *International Journal of Educational Technology*, *14*(5), 1–16. https://doi.org/10.1186/s41239-017-0045-2.

Essel, D. D., & Wilson, O. A. (2017). Factors Affecting University Students' Use of Moodle: An Empirical Study Based on TAM. *International Journal of Information and Communication Technology Education*, *13*(1), 14–26. https://doi.org/10.4018/IJICTE.2017010102.

Esteban-Millat, I., Martínez-López, F. J., Huertas-García, R., Meseguer, A., & Rodríguez-Ardura, I. (2014). Modelling Students' Flow Experiences in an Online Learning Environment Modelling Students' Flow Experiences in an Online Learning Environment. *Computers & Education*, *71*. https://doi.org/10.1016/j.compedu.2013.09.012.

Falode, O. C. (2018). Pre-service Teachers' Perceived Ease of Use, Perceived Usefulness, Attitude and Intentions Towards Virtual Laboratory Package Utilization in Teaching and Learning of Physics. *Malaysian Online Journal of Educational Technology*, *6*(3). https://files.eric.ed.gov/fulltext/EJ1184206.pdf.

Fathema, N., Shannon, D., & Ross, M. (2015). Expanding The Technology Acceptance Model (TAM) to Examine Faculty Use of Learning Management Systems (LMS) in Higher Education Institutions. *Journal of Online Learning and Teaching*, *11*(2), 210–232.

Fishbein, M., & Ajzen, I. (1975). *Belief, Attitude, Intention and Behaviour: An Introduction to Theory and Research*. Reading, MA, Addison Wesley.

Freina, L., & Ott, M. (2015). A Literature Review on Immersive Virtual Reality in Education: State of the Art and Perspectives. *In the International Scientific Conference Elearning and Software for Education*, *1*(333). https://doi.org/10.12753/2066-026X-15-020.

Ghani, J., Supnick, R., & Rooney, P. (1991). The Experience of Flow in Computer-Mediated and in Face-to-Face Groups. *Proceedings of the Twelfth International Conference on Information Systems*. https://core.ac.uk/download/pdf/301364008.pdf.

Gunstone, R. F. (1991). *Reconstructing Theory from Practical Experience*. Practical Science.

Harahap, F., Nasution, N. E. A., & Manurung, B. (2019). The Effect of Blended Learning on Student's Learning Achievement and Science Process Skills in Plant Tissue Culture Course. *International Journal of Instruction*, *12*(1), 521–538. https://doi.org/10.29333/iji.2019.12134a.

Hasanah, N. U., Farihah, U., & Nasution, N. E. A. (2022). The Effect of Interactive Multimedia Adobe Flash Professional CS6 on Student Learning Outcomes of Excretion System Material Based on The Revised Bloom Taxonomy. *Proceeding Cgant Unej.* https://proceedingcgantunej.or.id/index.php/proceedingcgant/ article/view/10.

Hawkins, I., & Phelps, A. J. (2013). Virtual Laboratory vs. Traditional Laboratory: Which is more Effective for Teaching Electrochemistry?. *Chemistry Education Research and Practice*, *14*(4). https://doi.org/10.1039/C3RP00070B.

Kirschner, P. (1988). The Laboratory in Higher Science Education, Problems, Premises, and Objectives. *High Educ*, *17*, 81–98. https://doi.org/10.1007/BF00130901.

Koretsky, M., Kelly, C., & Gummer, E. (2011). Students' Perceptions of Learning in the Laboratory: Comparison of Industrially Situated Virtual Laboratories to Capstone Physical Laboratories. *Journal of Engineering Education*, *100*(540–573). https://doi.org/10.1002/j.2168-9830.2011.tb00026.x.

Koufaris, M. (2002). Applying the Technology Acceptance Model and Flow Theory to Online Consumer Behavior. *Information Systems Research*, *13*(2), 205–223. https://doi.org/10.1287/isre.13.2.205.83.

Lang, J. (2012). Comparative Study of Hands-on and Remote Physics Labs for First Year University Level Physics Students. *Transformative Dialogues: Teaching & Learning Journal*, *6*(1), 1–25. https://journals.kpu.ca/index.php/td/article/view/1363/817.

Lee, M. C. (2010). Explaining and Predicting Users' Continuance Intention Toward E-Learning: An Extension of the Expectation-confirmation Model. *Computers & Education*, *54*(2), 501–516. https://doi.org/10.1016/j.compedu.2009.09.002.

Lee, M. K. O., Cheung, C. M. K., & Chen, Z. (2005). Acceptance of Internet-based Learning Medium: The Role of Extrinsic and Intrinsic Motivation. *Information & Management*, *42*(2), 1095–1104. https://doi.org/10.1016/j.im.2003.10.007.

Li, D., & Browne, G. J. (2006). The Role of Need for Cognition and Mood in Online Flow Experience. *Journal of Computer Information Systems*, *46*(1), 11–17.

https://doi.org/10.1080/08874417.2006.11645894.

Liao, S., Hong, J.-C., Wen, M.-H., Pan, Y.-C., & Wu, Y. (2018). Applying Technology Acceptance Model (TAM) to Explore Users' Behavioral Intention to Adopt a Performance Assessment System for E-book Production. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(10), 1–12. https://doi.org/10.29333/ejmste/93575.

Liu, I. F., Chen, M. C., Sun, Y. S., Wible, D., & Kuo, C. A. (2010). Extending the TAM Model to Explore the Factors that Affect Intention to Use an Online Learning Community. *Computers and Education*, *54*, 600–610. https://doi.org/10.1016/j.compedu.2009.09.009.

Liu, S. H., Liao, H. L., & Pratt, J. A. (2009). Impact of Media Richness and Flow on E-learning Technology Acceptance. *Computers and Education*, *54*. https://doi.org/10.1016/j.compedu.2008.11.002.

Mahfouz, A. Y., Joonas, K., & Opara, E. U. (2020). An Overview of and Factor Analytic Approach to Flow Theory in Online Contexts. *Technology in Society*, *61*. https://doi.org/10.1016/j.techsoc.2020.101228.

Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding Immersive Virtual Reality to a Science Lab Simulation Causes More Presence but Less Learning. *Learning and Instruction*, *60*(225–236). https://doi.org/10.1016/j.learninstruc.2017.12.007.

Moakofhi, K. M., Phiri, T. V., Leteane, O., & Bangomwa, E. (2019). Using Technology Acceptance Model to Predict Lecturers' Acceptance of Moodle: Case of Botswana University of Agriculture and Natural Resources. *Literacy Information and Computer Education Journal*, *10*(1). https://doi.org/10.20533/licej.2040.2589.2019.0407.

Moon, J. W., & Kim, Y. G. (2001). Extending the TAM for a World-Wide-Web Context. *information & management*, *38*(4), 217–230. https://doi.org/10.1016/s0378-7206(00)00061-6.

moro, c., stromberga, z., & stirling, a. (2017). Virtualisation Devices for Student Learning: Comparison Between Desktop-based (Oculus Rift) and Mobile-based (Gear VR) Virtual Reality in Medical and Health Science Education. *Australasian Journal of Educational Technology*, *33*(6), 1–10. https://doi.org/10.14742/ajet.3840.

Nasution, N. E. A. (2023). Using Artificial Intelligence to Create Biology Multiple Choice Questions for Higher Education. *Agricultural and Environmental Education*, *2*(1), 1–11. https://doi.org/10.29333/agrenvedu/13071.

Pramono, S. E., Prajanti, S. D. W., & Wibawanto, W. (2019). Virtual Laboratory for Elementary Students. International Conference on Education. *Science and Technology*. https://doi.org/10.1088/1742-6596/1387/1/012113.

Pyatt, K., & Sims, R. (2012). Virtual and Physical Experimentation in Inquiry-based Science Labs: Attitudes, Performance and Access. *Journal of Science Education and Technology*, *21*(1), 133–147. https://doi.org/10.1007/s10956-011-9291-6Q.

Rai, R. S., & Selnes, F. (2019). Conceptualizing Task-technology Fit and the Effect on Adoption – A Casestudy of a Digital Textbook Service. *Information & Management*, *56*(8), 1–10. https://doi.org/10.1016/j.im.2019.04.004.

Rauniar, R., Rawski, Yang, J., & Johnson, B. (2014). Technology Acceptance Model (TAM) and Social Media Usage: An Empirical Study on Facebook. *Journal of Enterprise Information Management*, *27*(1), 6–30. https://doi.org/10.1108/JEIM-04-2012-0011.

Romdaniyah, S., Nasution, N. E. A., & Rizka, C. (2023). Analysis of Biology Learning Planning on Plant Tissue Course in the Independent Learning Activity Unit (UKBM) based on Scientific Approach Class XI MIPA 5 at MAN Sumenep. *META: Journal of Science and Technological Education*, *2*(2). https://meta.amiin.or.id/index.php/meta/article/view/57.

Sun, K., Lin, Y., & Yu, C. (2008). A study on Learning Effect Among Different Learning Styles in a Web-based Lab of Science for Elementary School Students. *Computers & Education*, *50*. https://doi.org/10.1016/j.compedu.2007.01.003.

Syahfitri, F. D., Manurung, B., & Sudibyo, M. (2019). The Development of Problem Based Virtual Laboratory Media to Improve Science Process Skills of Students in Biology. *International Journal of Research & Review*, *6*(6). https://www.ijrrjournal.com/IJRR_Vol.6_Issue.6_June2019/IJRR0012.pdf.

Tatli, Z., & Ayas, A. (2013). Effect of a Virtual Chemistry Laboratory on Students' Achievement. *Educational Technology & Society*, *16*(1), 159–170. http://www.ifets.info/journals/16_1/14.pdf.

Teo, T. (2010). Examining the Influence of Subjective Norm and Facilitating Conditions on the Intention to Use Technology Among Pre-service Teachers: A Structural Equation Modeling of an Extended Technology Acceptance Model. *Asia Pacific Education Review*, *11*(253–262). https://doi.org/10.1007/s12564-009-9066-4.

Teo, T. Sang, G., Mei, B., & Hoi, C. K. W. (2018). Investigating Pre-service Teachers' Acceptance of Web 2.0 Technologies in their Future Teaching: a Chinese perspective. *Interactive Learning Environments*, *27*(4). https://doi.org/10.1080/10494820.2018.1489290.

Teo, T., Zhou, M., Fan, A. C. W., & Huang, F. (2019). Factors that Infuence University Students' Intention to use Moodle: A Study in MacAU. *Education Tech Research Dev*, *67*, 749–766. https://doi.org/10.1007/s11423-019-09650-x.

Yasa, N. N., Ratnaningrum, L. P., & Sukaatmaja, P. G. (2014). The Aplication of Technology Acceptance Model on Internet Banking Users in the City of Denpasar. *Manajemen Dan Kewirausahaan*, *16*(2), 93–102. https://doi.org/10.9744/jmk.16.2.93-102.

Zain, F. M., Hanafi, E., Don, Y., Yaakob, M. F. M., & Sailin, S. N. (2019). Investigating Student's Acceptance of an EDMODO Content Management System. *International Journal of Instruction*, *12*(4), 1–16. https://doi.org/10.29333/iji.2019.1241a.

Zhang, Y., & Wang, F. (2022). *Developments and Trends in Flow Research Over 40 Years: A Bibliometric Analysis*. PsyArXiv Preprints. https://doi.org/10.31234/osf.io/scuwf.

Zhao, J., & Wang, J. (2020). Health Advertising on Short-Video Social Media: A Study on User Attitudes Based on the Extended Technology Acceptance Model. *International Journal of Environmental Research and Public Health*, *17*. https://doi.org/10.3390/ijerph17051501.

Ziraba, A., Akwene, G. C., Nkea, A. N. A. M., & Lwanga, S. C. (2020). The Adoption and Use of Moodle Learning Management System in Higher Institutions of Learning: a Systematic Literature Review. *American Journal of Online and Distance Learning*, *2*(1), 1–21. https://doi.org/10.47672/ajodl.489.