ISSN: 2993-8678

Research Article

Current Trends in Mass Communication

The Effectiveness of Metaverse in e-Learning

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Submitted: 2024, Sep 10; **Accepted**: 2024, Oct 04; **Published**: 2024, Oct 28

Citation: Koppelaar, H., Tabrizi, S. S., Etaati, A., Moeini, A. (2024). The Effectiveness of Metaverse in e-Learning. *Curr Trends Mass Comm, 3*(1), 01-12.

Abstract

Via application of a 3D model to teach students a topic in astronomy, feedback on their experiences was evaluated via a questionnaire. The purpose of delivering this content via virtual reality was to assess participants' attitudes toward this technology and identify the factors that influence their willingness to use it. The analysis of students' responses to the questions revealed that user interface had a significant impact on their attitudes, which in turn indeed increased their willingness to use immersive technology in e-learning. The study applied the Partial Least Squares (PLS-SEM) analytical method to construct structural equations. For this purpose, survey data were collected from a comprehensive questionnaire distributed between 122 students of an educational institute in Iran. All the people present in this institution participated after undergoing special training compatible with virtual reality and metaverse techniques. So, in this study, the sample is the institute's population. The results confirm six hypotheses about positive relationships between facilitating conditions and usability of metaverse technology for students' attention and study motivation.

Keywords: Metaverse, Immersive Education, 3D Based Education, Metaverse-Based Education

1. Introduction

The COVID-19 pandemic has had far-reaching consequences for the world. According to a report, until January 19, 2024, nearly 774 million cases have been detected and the virus has caused 7 million confirmed deaths [1]. Another significant consequence of the Covid-19 pandemic was the temporarily closure of schools and higher education institutions. This closure of educational institutions during the pandemic has resulted in widespread adoption of technology to facilitate distance learning, much like what occurred during the previous outbreaks of viruses such as Influenza [2,3].

During the pandemic, traditional remote learning mainly was based on Computer Based Training, 2D instruction, was often found to be tedious [4]. 3D learning, on the other hand, offers immersive advantage compared to 2D instruction. The metaverse concept for instruction can incorporate games, simulations, virtual worlds, and unique learning opportunities unavailable in traditional 2D alternatives [5].

The three types of 3D technologies: augmented reality, mirror world, and virtual reality immerse students beyond 2D experience. Augmented reality expands the real world with added information through location-aware systems and interfaces. The mirror world is an enhanced virtual model of the real world that is convenient and efficient. Virtual reality simulates the inner world and creates immersive experiences using 3D graphics and avatars [6]. We can utilize all these technologies in immersive education for distance learning.

Metaverse is known as one of the world's emerging technologies. During the Corona epidemic, all educational services around the world were conducted E-Learning. During this period, special attention was paid to metaverse techniques, which was very interesting for us, in which conditions the use of this technique

will be used more quickly by the audience. Considering that the application of emerging technologies in different societies has various feedback loops, some of which are considered to be differences of views and differences in the environment in that society, we have come to the conclusion that by starting this research we can find out what the influencing factors are. The decision was to study the further use of Metaverse in the field of education. The interdisciplinary IT and management sciences in which this project took place, specializes in cultural factors and fields of technology and knowledge development in societies.

The research reported in this paper has been conducted using field research based on the Technology Acceptance Model (TAM), and the data has been collected and analyzed using SmartPLS 4 software. The aim and motivation of this study are to identify the influential factors and their impact on usage satisfaction in immersive and three-dimensional education.

2. Related Works

Onggirawan et al. conducted a systematic literature review on the adaptation of the distance learning process during the Covid-19 pandemic using virtual spaces in Metaverse [7]. Based on many previous studies, the results showed that the learners mostly enjoyed online learning. Metaverse as a learning method was more effective than traditional textbook-based and face-to-face learning methods, because the Metaverse enhances productivity, reduces costs, and promotes a more sustainable work environment. Previous studies have explored the transformative potential of AR and VR in education, significantly promoting student engagement [8]. Research confirms this effect in different areas, such as medical events for medical students [9]. By studying previous literature, we find that the Metaverse has been recognized as a technology and the next generation of social connections [10]. Although it is still in an emerging stage, it encompasses products and services that are available commercially, including social networks, cryptocurrencies, online games, and NFTs [11].

The deeper the immersion in an environment, the less aware learners are of their presence in a virtual world. Because the Metaverse can simulate more senses than traditional e-learning methods, it has a positive influence on students' learning process [12]. Suh and Ahn carried out a survey among 339 Korean elementary students [13]. They used the 18-measurement factors of Metaverse. The results were statistically analyzed and showed that 97.9% of learners had experienced using Metaverse previously and 95.5% of them found it to be close to their daily lives. Using Metaverse was enjoyed by the students, because they believed they were exposed to a form of entertainment.

Sukendro et al. studied the extended TAM to learn about the Indonesian sport science learners' use of e-learning during Covid-19 pandemic [14]. The study was conducted by surveying 974 learners. Partial Least Squares Structural Equation Modeling was used to measure and evaluate the proposed model. The results showed that TAM-based scale was useful in explaining factors that predict the use of e-learning among Indonesian sport science students during the pandemic. The findings also reported a significant relationship between facilitating condition and perceived ease of use on one hand, and between facilitating condition and perceived usefulness on the other hand. Furthermore, a significant relationship was fond between core components of TAM and perceived usefulness and students' attitudes.

Sayardoost Tabrizi et al. conducted a study on TAM-based model for evaluating the learner satisfaction with e-learning services [15]. The model was analysed by factor analysis, while Cronbach's alpha was applied to measure the reliability of the study instrument. Further, Partial Least Square (PLS) analytical method was employed to construct structural equations. 143 learners out of 334 participated in the project. The findings of the study revealed that the proposed TAM-based scale successfully explained factors predicting learners' satisfaction with e-learning services. Also, it was known that technical knowledge contributed to the perceived ease of use and impacted the perceived usefulness of e-learning services. Finally, a significant relationship was found between the learners' technical knowledge and their attitude toward e-learning.

Mseleku conducted a literature review focusing on the impact of the Covid-19 pandemic on higher education, specifically e-learning and e-teaching [16]. The findings revealed that academic institutes face some challenges during employing e-learning services, particularly for learners from rural areas and low-income families. The review also highlighted the prevalence of stress, depression, and anxiety among academics and learners. Factors related to learners' satisfaction with e-learning during the Covid-19 pandemic were identified in [17]. Dengel et al. highlighted factors influencing learning in Educational Virtual Environments (EVEs), emphasizing presence as a crucial factor, which is affected by objective (immersion) and subjective factors [18]. These factors have been integrated into the Educational Framework for Immersive Learning within Helmke's model, providing an initial educational perspective on immersive learning for further empirical evaluation.

Furthermore, research has been conducted by Mystakidis in the field of immersive virtual reality (IVR) technology used in education and training through game-based simulations [19]. Klamma et al. introduced a gamified Mixed Reality environment for creating educational Escape Rooms in an efficient manner [20]. The study included the development of two games for different subjects, demonstrating the feasibility of this approach through an evaluation at a high school.

Mystakids focused on the impact of playful learning in Social Virtual Reality (SVR) within distance and open education settings [21]. This study aimed to provide a practical framework for playful learning by examining three case studies in the United States and Greece. The findings showed that engaging in playful learning experiences in SVR can enhance academic interest, intrinsic motivation, engagement level, satisfaction, and completion rates.

In a related study the effects of immersive virtual reality (IVR)

nature-trail tours and hiking tours on science learning, self-efficacy, cognitive load, enjoyment, and usefulness were compared. Results showed that the IVR tour based on the Cognitive Theory of Multimedia Learning improved science learning and self-efficacy without increasing cognitive load. It was also as enjoyable as hiking tours [22]. Designing IVR environments can improve science learning outcomes and promote the accessibility of nature-based sites.

An early study of the role of interactive exosomatic forms of memory in learning in the Metaverse, surpassing books, museums, and personal storage [28].

Taking inspiration from the prior scholarly literature, this study examines the factors that impact user satisfaction in web-based and 3D virtual reality learning. These factors have been investigated using a TAM framework to ultimately achieve user satisfaction.

Satisfaction of student users with the e-learning management system of the University of Tehran during the Corona era was investigeated using a TAM and ELQ approach to analyze factors affecting user satisfaction, with a focus on UI/UX and information quality [29]. The results show that these factors positively impact the technical quality of the service, ultimately increasing user satisfaction.

A recent literature review of 35 empirical analyses conducted using different theories of information systems TAM, UTAUT, TPM and extensions, indicates that education in the Metaverse is influenced by multiple factors [30]. The factors fall into three classes: individual, technological and environmental level, and include effort expectancy, behavioral intention, self-efficacy, satisfaction and immersion. A visionary study [26] concludes that the Metaverse has the potential to become a transformative platform for teaching and learning, although it currently faces some challenges.

3. Materials and Methods

This article presents a TAM that demonstrates the estimation of user satisfaction, which is the target variable of the current study all variables and hypotheses illustrated in Figure 1.

3.1 Hypotheses

Based on the relationships in model 1, the following research hypotheses are formulated to conduct the study:

1) Hypothesis 1:
The relationship between Facilitating Condition and Perceived Usefulness is positive.
2) Hypothesis 2:
The relationship between User Interface UI and Attitude is positive.
3) Hypothesis 3:
The relationship between UI and Behavioral Intention BI is positive.

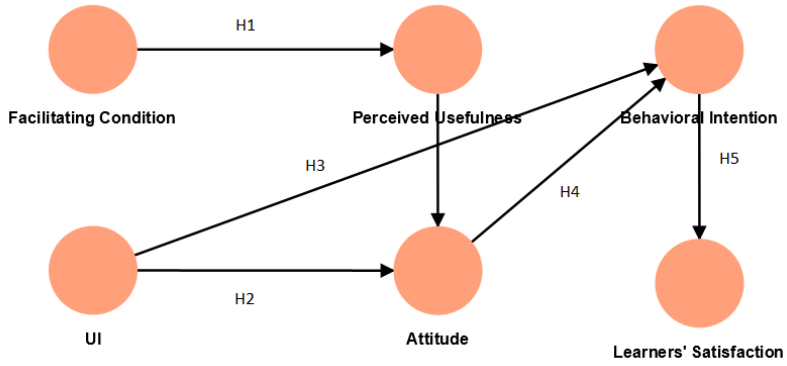

Figure 1: Proposed Model and all Hypotheses

4) Hypothesis 4:
The relationship between Attitude and BI is positive.
5) Hypothesis 5:
The relationship between Behavioral Intention BI and Learners' Satisfaction LS is positive.
6) Hypothesis 6:
The relationship between Perceived Usefulness and Attitude is positive.

The concept of "Facilitating Condition" refers to the conditions that promote learning. These conditions can include better language skills for writing (educational content), creating websites, etc.

"Perceived Usefulness" says how useful the educational content provided on the website is found by the user or student.
The term "UI" refers to the visual beauty of the website on which education is provided. Additionally, the term "Attitude" refers to the user's perspective or approach towards 3D education.
"Behavioral Intention" means the likelihood or extent to which a user may use 3D or immersive learning for learning and teaching in the present or future.
Finally, "Learners' Satisfaction" refers to the extent of user satisfaction with the education received through the 3D website.

3.2 Participants

The participants consisted of females (47.8%) and men (52.2%). Their fields of study varied, and included basic sciences; medical and experimental sciences; technical and engineering sciences; humanities and arts. 70.5% of the participants were graduates or learners in technical and engineering sciences. The participants there were visitors to Metaverse Kish Laboratory or students of Tehran University, International Kish Campus.

3.3 Instrumentation

We adapted the concept presented on the Metis website http://www.project-metis.com/ and implemented it in the institutes' offline format for utilization with virtual reality glasses. The software 3D-Vista facilitates virtual tours on virtual reality headsets. Ultimately, our aim was to deliver a straightforward training module that is familiar to the audience, presenting it in an innovative format. This approach enables us to specifically assess the effectiveness of training (specially e-learning) within the virtual reality platform, which is one of the main criteria of the Metaverse, in the context of e-learning.

A questionnaire for evaluation was distributed among the participants through Google Forms. The questionnaire consisted of 26 key indicators and four socio-demographic questions. Each of the indicators represented a facet of the 6-factor model. Smart PLS 4 software was used to examine the effect of the factors. It should be noted that five of the 26 indicators were eliminated due to their low correlation with the latent variable, reducing the total number of the indicators to twenty one.

3.4 Procedure

We adapted the concept presented on the Metis website and implemented it in an offline format for utilization with virtual reality glasses.The participants were first asked to review the website http://www. Project-metis.com and then respond to the questions provided through Google Forms. After that, the results were extracted as an Excel file and used as a CSV file input for the Smart PLS software.

4. Results

In this study, a descriptive method was used to select an appropriate measurement model for testing the reliability and validity of the measurements. Three measurements were considered in this study: the impact of latent factors, the correlation between observed and latent variables, and validity and reliability.

The latent factors demonstrate the extent to which each construct is correlated with itself and the degree of correlation between constructs. The correlation measures were assessed using Cronbach's alpha coefficient and composite reliability. The threshold values for these measures are reported following [27], with a Cronbach's alpha value greater than 0.7 and an Average Variance (AVE) Extracted value greater than 0.5. Figure 2 below also shows the AVE measure for the latent variables, which indicates the level of internal consistency and the strength of the relationships between indicators. In addition, the reported values in Table 1 below indicate that there is a satisfactory correlation between the structural variables in the proposed model.

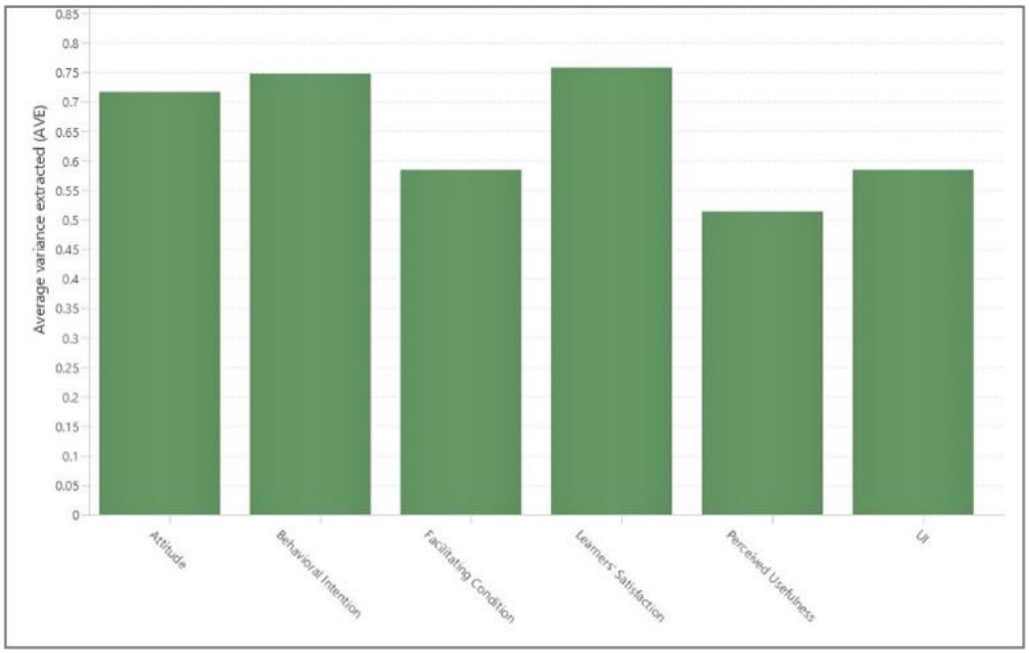

Figure 2: Average Variance Extracted Results

	Observed VAR	Factor Loading	Cronbach's alpha	Composite Reliability	AVE
Attitude	AT1	0.865	0.866	0.900	0.910
	AT2	0.891			
	AT3	0.882			
	AT3	0.738			
Behavioral Intention	BI1	0.896	0.887	0.901	0.922
	BI2	0.916			
	BI3	0.827			
	BI4	0.816			
Facilitating Condition	FC3	0.899	0.319	0.387	0.730
	FC4	0.601			
Learners' Satisfaction	SUE1	0.836	0.902	0.896	0.926
	SUE2	0.855			
	SUE3	0.875			
	SUE4	0.913			
Perceived Usefulness	PU1	0.771	0.689	0.693	0.807
	PU2	0.675			
	PU3	0.634			
	PU4	0.777			
UI	U12	0.756	0.664	0.735	0.807
	UI3	0.677			
	UI6	0.850			

Table 1: Construct Reliability and Validity

4.1 Discrimiannt Validity

Discriminant validity refers to the degree of difference between each construct and other constructs, as indicated by the Fornell-Larcker report. According to this report, the AVE value for each construct in the Smart PLS software should be less than the squared correlation between that construct and all other constructs.

Table 2 represents a lower triangular matrix, where the diagonal entries are the largest values in each row. This signifies that the observed indicators accurately capture their corresponding latent variables; or in other words, each construct adequately measures its own underlying concept.

	AT	BI	FC	LS	PU	UI
AT	0.846					
BI	0.779	0.865				
FC	0.368	0.502	0.764			
LS	0.859	0.814	0.357	0.870		
PU	0.557	0.593	0.385	0.469	0.717	
UI	0.548	0.457	0.279	0.446	0.576	0.764

Table 2: Fornell Larcker

Discriminant validity is assessed through cross-loadings, which indicate to what extent an indicator loads more heavily on its own construct compared to other constructs. When the factor loading of an indicator on a construct is higher than its loading on other constructs, it indicates discriminant validity.

4.2 Analysis

In this study, we initially had 26 observed variables. However, five of them (FC1, FC2, UI1, UI4, UI5) were removed from the analysis due to their weak correlation with the latent variable. This reduced the total number of variables to 21. The construct validity was assessed using the Average Variance Extracted (AVE), which was found to be above 0.5 for all constructs, indicating high measurement accuracy and precision, as shown in Figure 2 and Table 1.

To further evaluate the measurement model, we examined the factor loadings and the correlation between the latent and observed variables, as presented in Table 1. This analysis allowed us to reach reliable conclusions regarding the relationships between the variables. Additionally, we calculated Cronbach's alpha, a measure of internal consistency reliability, for the observed variables.

Moreover, we investigated the presence of cross-loadings, which occur when an observed variable shows a relatively high correlation with multiple latent variables. This analysis helps to identify potential influences from multiple underlying constructs on the observed variable. The results of the cross-loading analysis are also presented in Table 1.

By considering both the cross-loadings and Cronbach's alpha values, we were able to evaluate the relationships between the observed and latent variables and assess the Overall reliability of the measurement model [27].

Additionally, it is worth mentioning that the observed variables, namely Attitude, Behavioral Intention, and Learner's Satisfaction have Cronbach's alpha values of 0.866, 0.887, and 0.902, respectively. These high Cronbach's alpha values indicate a high level of internal consistency and reliability for these variables. This signifies their importance and reliability in the study.

4.2.1 Determination of Factor R^2

R-square is used to assess the prediction accuracy of the proposed model. It represents the proportion of the variance in the dependent variable (latent variable) that can be explained by the independent variable (observed variable). In other words, it indicates how well the observed variable predicts the latent variable. The R-square coefficient is obtained as the square of the correlation coefficient between the variables or as the output value of regression analysis.

In Table 3, the R-square coefficients for the variables in the proposed model are provided. These coefficients help to evaluate the strength of the relationship between the observed and latent variables. If the R-square coefficient is less than 0.25, it suggests a weak correlation between the variables. If it falls within the range of 0.25 to 0.75, it indicates an moderate correlation. Finally, if the coefficient is greater than 0.75, it indicates a strong correlation between the structural variables.

In summary, the R-square coefficient serves as a measure of the predictive power of the observed variable in relation to the latent variable. Its values range from 0 to 1, with higher values indicating a stronger correlation and better prediction accuracy.

	R square	Correlation
Attitude	0.388	Average
Behavioral Intention	0.609	Average
Learners' Satisfaction	0.662	Average
Perceived Usefulness	0.148	Weak

Table 3: R –Square Results

4.2.2 Path Co-Efficiency Results

The six hypotheses in Table 4 and Figure 3 are to evaluate the coefficients between the paths of observed and latent variables using the Bootstrap algorithm with a running sample of 5000 in SmartPLS with a significance level of 5%. If the p-value is less than 0.05 or the T-statistics is greater than 1.96, it indicates a significant relationship between the two independent variables [14]. As evident from the obtained results, all the hypothesized relationships in the proposed model exhibit a highly significant level of significance.

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values	Significance
Attitude -> Behavioral Intention	0.756	0.75	0.066	11.383	0.000	Yes
Attitude -> Learners' Satisfaction	0.615	0.614	0.071	8.695	0.000	Yes
Behavioral Intention -> Learners' Satisfaction	0.814	0818	0.037	21.981	0.000	Yes
Facilitating Condition -> Attitude	0.139	0.150	0.057	2.414	0.016	Yes
Facilitating Condition -> Behavioral Intention	0.105	0.113	0.047	2.238	0.025	Yes
Facilitating Condition -> Learners' Satisfaction	0.085	0.093	0.039	2.177	0.030	Yes
Facilitating Condition -> Perceived Usefulness	0.385	0.405	0.089	4.595	0.000	Yes
Perceived Usefulness -> Attitude	0.360	0.369	0.117	3.073	0.002	Yes
Perceived Usefulness -> Behavioral Intention	0.272	0.279	0.099	2.764	0.006	Yes
Perceived Usefulness -> Learners' Satisfaction	0.222	0.229	0.084	3.649	0.008	Yes
UI -> Attitude	0.341	0.342	0.0104	3.289	0.001	Yes
UI -> Behavioral Intention	0.300	0.304	0.100	3.012	0.003	Yes
UI -> Learners' Satisfaction	0.244	0.249	0.082	2.976	0.003	Yes

Table 4: Path Co-Efficiency Results

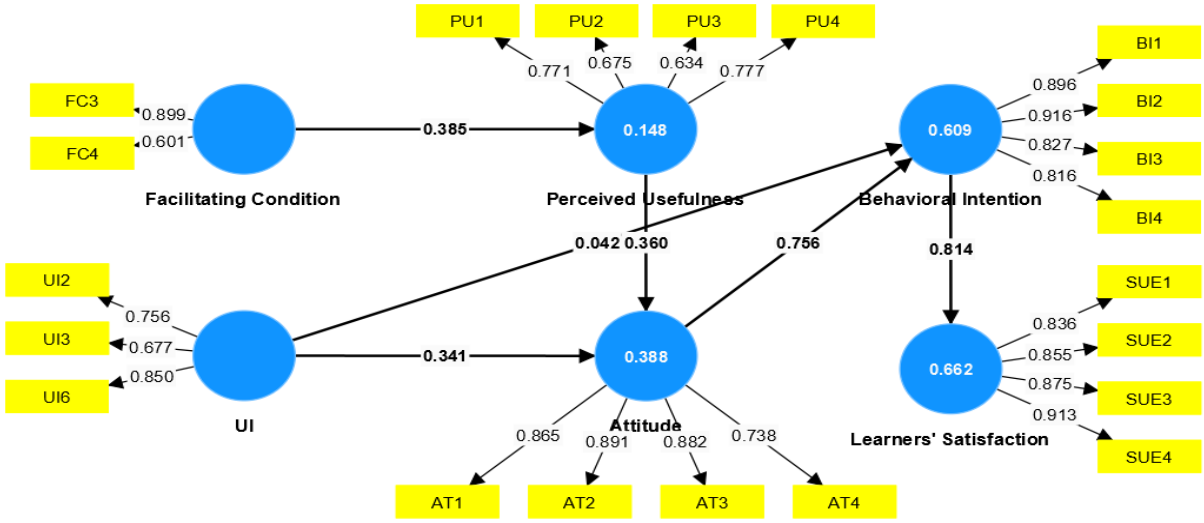

Figure 3: Results of Structural Model

5. Discussion

After six years of investing time and money in Computer Based Training (CBT) and accompanying psychometric research at Utrecht University (Department of Psychology), it was decided in 1981 to stop efforts in CBT. The problem was: keeping students engaged in lessons. Students were bored, they plainly walked away from the CBT terminals. The staff and administration of the Department became aware that the benefits of CBT were for the staff, but not for the students. And indeed, the administration and creation of statistics exams had been automated, and new research had been published on new psychometric tests [4,28,29]. Moreover, the generation of multiple-choice exam items was parameterized, so that additional retakes were easily possible without having to create a new exam from scratch.

With the historic debacle of CBT in mind, this article reposrts an encouraging test result. Modern tools—compared to those of some 43 years ago—enable in the Metaverse to provide the technology in a facilitating condition, that apparently is needed to keep students engaged.

6. Conclusion

All assumptions have been proven based on the Path Co-Efficiency table, and no assumption has been rejected because all

P-values were less than 0.05 or T-Statistics were greater than 1.96. Additionally, according to the AVE diagram, all measurements have been performed with good accuracy. Furthermore, Fornell Larcker is presented as a lower triangular matrix, where diagonal entries are the largest values in each row. However, considering Cronbach's alpha in the Construct Reliability and Validity table and R- square, the adoption of immersive websites in the field of education in Iran is still in the culturalization stage, and further stimulation of Metaverse use is needed. So, to deliver engaging education, it is necessary to take effective steps to introduce and become familiar with this technology.

Future Reseach

We plan to repeat this research in universities that have the facilities of metaverse-based education in order to examine the views of the country's academic community in this regard. Also, the author S.S.T considers extending this research with colleagues in other universities, such as Delft University of Technology (TU Delft), and partner centers in Australia (e.g. the University of New South Wales (NSW)). He intends to compare results from such collaborative future research works.

Author Contributions

Conceptualization, S. S. T., Methodology, A. M., Software, A. E., Validation, S. S. T. and A. M., Formal ANALYSIS, A.,E., S. S. T., Investigation, A. E., Resources, S. S. T., H.K.; Data Curation, A. E., A. M., Writing-Original Draft Preparation, A. E., Writing-Review and Editing, A. E., S. S. T. , A.M. and H. K., Visualization, A. E., Supervision, A. M., All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Informed Consent Statement

Informed consent was obtained from all participants involved in the study.

Data Availability Statement

The data are available in Appendices A and B, below.

Acknowledgments

The authors thank Mr. Esfandiar Magsoudi for his generously available public web platform http://www.project-metis.com/. Also we thank professor (in English literature) Dr. Maleki for his correction of the manuscript. H.K. and A.E. thank Dr. Peyman Nasehpour for his inspiration to collaborate in this research. HK thanks Mr. Piet de Wijs for historic information about CBT. We thank the three reviewers for their critical remarks to improve the paper.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1. World Health Organization (WHO), COVID-19 epidemiological update, 19 January 2024,
2. Isfeld-Kiely, H., & Moghadas, S. (2014). *Effectiveness of School Closure for the Control of Influenza.* National Collaborating Centre for Infectious Diseases.
3. Poinsignon, L. (2020). On the shoulders of giants: recent changes in Internet traffic. *Cloudflare. https//blog. cloudflare. com/on-the-shouldersofgiants-recent-changes-in-internet-traffic/(accessed 20 May 2020.*
4. Mellenbergh, G. J., Koppelaar, H., & van der Linden, W. J. (1977). Dichotomous decisions based on dichotomously scored items: a case study. *Statistica Neerlandica, 31*(4), 161-169.
5. Hwang, Y., Shin, D., & Lee, H. (2023). Students' perception on immersive learning through 2D and 3D metaverse platforms. *Educational technology research and development, 71*(4), 1687-1708.
6. Kye, B., Han, N., Kim, E., Park, Y., & Jo, S. (2021). Educational applications of metaverse: possibilities and limitations. *Journal of educational evaluation for health professions, 18.*
7. Onggirawan, C. A., Kho, J. M., Kartiwa, A. P., & Gunawan, A. A. (2023). Systematic literature review: The adaptation of distance learning process during the COVID-19 pandemic using virtual educational spaces in metaverse. *Procedia computer science, 216,* 274-283.
8. Geroimenko, V. (Ed.). (2024). *Augmented and Virtual Reality in the Metaverse.* Springer International Publishing AG.
9. Momosaki, R., Shirai, Y., Nagano, F., Sakamoto, R., & Tora, K. (2024). Beyond Real Congress: Academic Congress in the Metaverse Provides Exciting and Novel Educational Experience. *Progress in Rehabilitation Medicine, 9*, 20240020.
10. Hwang, G. J., & Chien, S. Y. (2022). Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective. *Computers and Education: Artificial Intelligence, 3,* 100082.
11. Gupta, R., & Pal, S. K. (2023). Introduction to Metaverse: Technology Landscape, Applications, and Challenges. Chapter 1.3: Evolution of Metaverse, 1.3.1 Phase 1: Emerging Metaverse. ISBN: 978-981-99-7396-5; eBook ISBN: 978-981-99-7397-2
12. Kreutzer, R. T., & Klose, S. (2023). *Next Stop Metaverse*. Springer.
13. Suh, W., & Ahn, S. (2022). Utilizing the metaverse for learner-centered constructivist education in the post-pandemic era: An analysis of elementary school students. *Journal of intelligence, 10*(1), 17.
14. Sukendro, S., Habibi, A., Khaeruddin, K., Indrayana, B., Syahruddin, S., Makadada, F. A., & Hakim, H. (2020). Using an extended Technology Acceptance Model to understand students' use of e-learning during Covid-19: Indonesian sport science education context. *Heliyon, 6*(11).
15. Sayardoost Tabrizi, S., Sabzian, A., Moeini, A., & Yakideh, K. (2023). TAM-Based Model for Evaluating Learner Satisfaction of E-Learning Services Case Study: E-Learning

System of University of Tehran. *International Journal of Web Research, 6*(1), 105-112.
16. Mseleku, Z. (2020). A literature review of E-learning and E-teaching in the era of Covid-19 pandemic.
17. Yekefallah, L., Namdar, P., Panahi, R., & Dehghankar, L. (2021). Factors related to students' satisfaction with holding e-learning during the Covid-19 pandemic based on the dimensions of e-learning. *Heliyon, 7*(7).
18. Dengel, A., & Mägdefrau, J. (2018, December). Immersive learning explored: Subjective and objective factors influencing learning outcomes in immersive educational virtual environments. In *2018 IEEE international conference on teaching, assessment, and learning for engineering (TALE)* (pp. 608-615). IEEE.
19. Mystakidis, S., Besharat, J., Papantzikos, G., Christopoulos, A., Stylios, C., Agorgianitis, S., & Tselentis, D. (2022). Design, development, and evaluation of a virtual reality serious game for school fire preparedness training. *Education Sciences, 12*(4), 281.
20. Klamma, R., Sous, D., Hensen, B., & Koren, I. (2020). Educational escape games for mixed reality. In *Addressing Global Challenges and Quality Education: 15th European Conference on Technology Enhanced Learning, EC-TEL 2020, Heidelberg, Germany, September 14–18, 2020, Proceedings 15* (pp. 437-442). Springer International Publishing.
21. Mystakidis, S. (2021). Combat tanking in education: the TANC model for playful distance learning in social virtual reality. *International Journal of Gaming and Computer-Mediated Simulations (IJGCMS), 13*(4), 28-47.
22. Huang, X., Huss, J., North, L., Williams, K., & Boyd-Devine, A. (2023). Cognitive and motivational benefits of a theory-based immersive virtual reality design in science learning. *Computers and Education Open, 4,* 100124.
23. Liu, X., & Koppelaar, H. (2005). Adaptive Knowledge Exosomatics for E-Learning. In *Encyclopedia of Distance Learning* (pp. 38-43). IGI Global.
24. Tabrizi, S. S., Sabzian, A., & Moeini, A. (2024). A Hybrid Model for Evaluation of E-Learning User Satisfaction with TAM and ELQ Approach. *Int J Inf Comm Techn Res*, 45-54.
25. Al-kfairy, M., Ahmed, S., & Khalil, A. (2024). Factors impacting users' willingness to adopt and utilize the metaverse in education: A systematic review. *Computers in Human Behavior Reports,* 100459.
26. Onu, P., Pradhan, A., & Mbohwa, C. (2024). Potential to use metaverse for future teaching and learning. *Education and Information Technologies, 29*(7), 8893-8924.
27. Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European business review, 31*(1), 2-24.
28. Mellenbergh, G. J., & Van der Linden, W. J. (1979). The internal and external optimality of decisions based on tests. *Applied Psychological Measurement, 3*(2), 257-273.

Appendix A: the Questions

Questions: (translated to English from Persian)

Scales: I'm totally in agreement: 5; I'm in agreement: 4; I have no idea: 3; I'm in disagreement: 2; I'm totally in disagreement: 1;

I can easily install the programs I intend.

TK1

I am a member of many social media platforms.

TK2

I immediately learn to work with a new social media.

TK3

I know how to work with software such as PowerPoint, Word and Excel.

TK4

The three-dimensionality of the planets has impressed me.

UI1

The ability to rotate the planets is a good feature that allows me to see all parts of the planets.

UI2

Pointing to details like the great ed spot of Jupiter is a positive point about this application in my opinion.

UI3

I think the coloring of the planets is very close to the reality.

UI4

The order of the planets is effective in learning the order of the planets of the solar system.
UI5

3D design of planets helps me to learn the content better.
UI6

In my opinion, it would be better if the website supported Farsi(Persian) in addition to English.
UX1

I can easily find any planet I want from the site menu.
UX2

I can easily open each planet's description.
UX3

I can easily move the planets in different directions.
UX4

It is completely clear to me that how I can use the website to learn astronomy.
PU1

Using the 3D model of the solar system has been very useful for me and I have been able to see the planets in a more realistic shape than 2D photos without a telescope or special equipment.
PU2

In my opinion, using 3D glasses to use the website and watch the planets can be an even more exciting experience.
PU3

Adding different languages, including Farsi(Persian), to the website can help in understanding the content better.
PU4

I have an acceptable internet speed while using the website
FC1

I have fluent in the languages in which the text of the website is presented (English or Portuguese).
FC2

A guide on how to use the website would improve my learning process.
FC3

I have someone to help me if I face computer bugs or crashes and help me with guiding me on how I can use software.
FC4

Using 3D-based education is a good idea for teaching astronomy.
AT1

In my opinion, 3D and immersive training is more efficient than regular 2D training
AT2

In my opinion, 3D-based and immersive education will be more used in scientific centers in the future.
AT3

In my opinion, 3D-based and immersive education can be used in all subjects and areas.
AT4

I feel good about using 3D-based training.
SUE1

In my opinion, 3D based and immersive education can cover educational needs in situations like Covid-19 pandemic, and I am happy about it
SUE2

I feel good that in the future I can replace conventional 2D-based training with 3D-based and immersive one.
SUE3

3D-based training gives me a better feeling than 2D one.
SUE4

I think in the future I will use 3D-based and immersive train training more than the 2D one.
BI1

I will recommend 3D-based and immersive training to my friends too.
BI2

In the future, I prefer to enter the 3D space with special virtual reality glasses than to see the normal 2D courses.
BI3

If I were a teacher, I would definitely try 3D-based and immersive websites to teach my students.
BI4

Appendix B the Data

TK1	TK2	TK3	TK4	UI1	UI2	UI3	UI4	UX1
4	2	4	4	3	3	3	3	4
4	4	4	5	4	4	4	2	5
4	2	2	4	4	4	4	4	4
5	5	5	4	4	4	4	4	5
5	5	5	4	4	4	4	4	4
4	4	4	4	4	5	4	3	5
5	4	5	5	4	4	4	4	4
5	2	4	5	4	5	4	2	4
5	4	5	4	5	3	3	4	4
5	5	5	4	3	4	4	4	3
5	4	5	5	5	5	1	4	4
5	4	4	5	4	5	3	4	5
5	4	4	5	4	4	4	4	1
5	5	5	5	5	4	4	2	5
4	1	4	4	4	4	4	4	4
4	4	4	5	5	5	5	5	4
5	4	5	5	5	5	5	4	4
5	4	5	4	4	5	5	3	4
5	5	5	5	4	4	5	5	5
4	4	4	5	5	5	5	5	4
5	4	5	5	2	3	3	3	4
4	4	4	5	5	5	4	4	5
5	4	4	3	3	4	4	3	5
5	5	5	4	4	4	5	3	5
4	3	5	5	5	5	4	2	5
2	5	5	5	2	4	4	2	3
5	4	5	5	5	5	5	4	4
5	4	5	5	4	4	5	4	3

4	2	5	5	5	4	5	5	5
4	4	4	4	3	3	3	3	4
5	5	5	5	4	4	3	3	4
4	4	4	4	4	4	4	2	4
5	4	5	5	5	4	4	4	3
5	4	5	5	3	4	3	4	2
2	4	4	5	2	3	3	1	4
5	4	4	5	3	4	3	2	3
3	2	3	4	5	5	4	4	5
3	2	3	4	5	5	5	5	5
5	3	5	5	5	5	5	5	5
5	4	4	5	5	3	3	3	4
5	5	5	5	5	5	5	4	4
5	4	4	5	5	5	5	4	5
5	5	5	5	3	4	4	4	5
5	5	5	5	4	4	4	4	5
5	4	4	4	4	5	5	5	5
5	4	5	5	5	5	5	4	5
5	2	5	4	5	5	5	4	3
5	5	5	5	4	4	5	4	3
5	2	5	4	2	4	5	4	4
4	3	4	4	2	3	3	2	5