Exploring New Horizons in Dental Education: Leveraging AI and the Metaverse for Innovative Learning Strategies

Amina Almarzouqi
Health Economic and Financing Group
University of Sharjah, Sharjah, UAE
amalmarzouqi@sharjah.ac.ae

Anissa Bettayeb
Head of Academic Computing Services Section, Information Technology Center, University of Sharjah, Sharjah, UAE
anissa@sharjah.ac.ae

Syed Azizur Rahman
Health Economic and Financing Group
University of Sharjah, Sharjah, UAE
syrahman@sharjah.ac.ae

Said Salloum
Health Economic and Financing Group
University of Sharjah, Sharjah, UAE
ssalloum@sharjah.ac.ae

Nabeel Al-Yateem
Health Economic and Financing Group
University of Sharjah, Sharjah, UAE
nalyateem@sharjah.ac.ae

Abstract*—the COVID-19 pandemic significantly disrupted dental education, hindering hands-on exposure to cutting-edge dental practices and advanced equipment worldwide. Amidst these challenges, the emergence of Metaverse-based learning has presented an innovative solution, fulfilling the growing need for remote educational opportunities in dentistry. Traditional online learning platforms like Zoom have proven inadequate for providing a comprehensive learning experience in dentistry, prompting a shift towards more engaging, immersive educational settings. This trend is especially evident in the dental education sector in the United Arab Emirates (UAE). This research delves into dental students' perceptions of how Metaverse technology aids in achieving their educational objectives within the UAE. Our analysis focuses on crucial factors that influence technology adoption, particularly 'Perceived Value' and 'Perceived Satisfaction'. We collected a substantial dataset of 89 responses from the College of Dental Medicine (CDM) at the University of Sharjah. To rigorously examine our research model, we applied Partial Least Squares-Structural Equation Modeling (PLS-SEM) and an advanced Machine Learning (ML) technique, based on data from our student survey. Our results highlight the Metaverse's critical role in guiding technology adoption decisions, strongly driven by 'Perceived Value' and 'Perceived Satisfaction'. Remarkably, the ML method demonstrated higher predictive accuracy in identifying the outcome variable compared to other analysis techniques. This research contributes to the scholarly conversation on artificial intelligence, especially its relationship with environmental sustainability, offering valuable insights for industry stakeholders, policymakers, and AI developers. The findings lay the groundwork for developing AI-powered solutions aligned with user preferences and environmental considerations.

Keywords— AI-Driven Learning Strategies, Dental Education Distance Learning Innovations, Metaverse, Technology Adoption.

I. INTRODUCTION

In the ever-evolving digital landscape, the push for innovation in specialized educational sectors has become more pronounced, particularly in dental education, where the need for advanced training methodologies is critical. The ubiquity of internet access coupled with the exponential growth of social media has dramatically reshaped the concept of three-dimensional (3D) virtual realities, rendering them both more accessible to a wider audience and more cost-efficient. Originating from the realms of science fiction, the 'Metaverse' is a term that encapsulates an immersive 3D world, blending aspects of our physical existence with digital environments to enable a depth of human interaction that was once thought impossible [1], thereby erasing the boundaries that separate our physical and digital existences [2]–[5].

Within the educational sphere, especially in the domain of dental education, the Metaverse is being leveraged to usher in a transformative era of learning. It utilizes avatars and immersive 3D settings to allow students to engage comprehensively with complex dental practices and scenarios, heralding a significant shift towards digitalized educational models. Research conducted by Jeon and Jung [6] highlights the immense potential the Metaverse holds in boosting student engagement and fostering an active learning culture within dental education. This digital infrastructure not only supports the interaction with avant-garde educational techniques but also encourages self-directed learning. Research, such as that by Kanematsu et al., [7] illuminates the diverse applications of the Metaverse in dental training, pointing towards the need for a holistic framework to assess its complete assimilation into educational practices.

Past studies have emphasized the importance of capturing user perspectives on the benefits brought about by technological advancements. While certain investigations have concentrated on the innovative nature of such technologies [8], others have examined their broad-ranging effects [9], [10]. Despite the recognized promise of the Metaverse, an in-depth exploration of its efficacy specifically within dental education — given its relatively recent emergence — remains scarce. This study aims to fill this void by identifying and analyzing the key factors

2836-3795/24/$31.00 ©2024 IEEE
DOI 10.1109/COMPSAC61105.2024.00298

influencing the Metaverse's adoption in dental education across the UAE. It will investigate aspects such as perceived usefulness, ease of adoption, and the overall value these digital environments add to the educational experience. Furthermore, this research will delve into how an individual's inclination towards innovation correlates with their perceived usefulness and ease of use of the Metaverse. By connecting concrete attributes like accessibility and the potential for trial runs to the perceived value and actual deployment of the Metaverse, this study seeks to offer insights into its practical application in enhancing dental education.

Fig. 1. Virtual dental practice

The landscape of academic research has frequently utilized linear data analysis methods, such as Structural Equation Modeling (SEM), to probe the dynamics between various factors. However, this reliance on linear correlations might not fully encompass the complexities inherent in decision-making processes, which often involve multifaceted and non-linear relationships. There's a growing discourse among researchers about the need to surpass the linear limitations of SEM by incorporating Machine Learning (ML) techniques, which offer a more nuanced exploration of data. Despite this, critiques by scholars such as Huang and Stokes [11] point out the prevalence of a basic application of ML in many studies, suggesting a gap in harnessing its full analytical power.

This study seeks to address these gaps by proposing a sophisticated hybrid model that combines SEM with advanced ML techniques, aiming to capture the nuanced dynamics of Metaverse adoption within the realm of dental education. By integrating the depth and flexibility of ML with the structured analytical framework of SEM, this approach endeavors to provide a richer understanding of the factors influencing the incorporation of virtual learning environments in educational settings.

The paper is organized to guide readers through a comprehensive exploration of this innovative research approach. Section II introduces the research model, specifically tailored to the context of Metaverse applications in dental education, setting the stage for a detailed examination of the technology's adoption. Section III details the methodology employed in this study, including the experimental design and data collection methods, ensuring transparency and replicability. Section IV delves into the analysis of the collected data, shedding light on the intricate patterns and insights that emerge in relation to the research questions posed. Finally, Section V brings the study to a conclusion by highlighting its key findings, discussing their implications for both academic research and practical application, and suggesting potential directions for future research. This concluding section emphasizes the significant role that advanced ML techniques can play in deepening our understanding of educational innovations and the adoption of cutting-edge learning technologies.

II. THEORETICAL FRAMEWORK AND HYPOTHESIS DEVELOPMENT

Fascinatingly, the concept of perceived value (PV) encompasses considerations of efficiency, including the effort and time invested, and it shares a connection with the intention to continue using technological innovations. Perceived value (PV) emerges as a cornerstone within business organizations, offering a critical lever for achieving competitive differentiation. This perceived value (PV) exerts a notable influence on user engagement across diverse spheres, ranging from intrinsic human values to entertainment, and exhibits a strong correlation with user satisfaction. Satisfaction, in turn, serves as a reliable predictor of the effectiveness of perceived value (PV). Consequently, perceived value (PV) is shaped by several core factors, including time, cost, satisfaction, and the overarching benefits derived.

The motivation to persist in using technology is significantly driven by perceived satisfaction (PS), which profoundly impacts users' attitudes and their valuation of experiences and utility. Satisfaction, therefore, is intricately linked to user expectations, with dissatisfaction arising when these expectations are not fulfilled. In the educational realm, particularly within the context of the Metaverse, the experience offered is characterized as richly vivid and immersive, significantly enhancing the quality of interactions within virtual environments. Thus, we propose the following hypotheses for exploration:

H1: PS would predict the PV.

H2: PV would predict the META.

H3: PS would predict the MATA.

In illustrating our conceptual framework, we utilize an integrated approach that combines Partial Least Squares Structural Equation Modeling (PLS-SEM) with Machine Learning (ML) algorithms. Figure 2 graphically displays these methodologies, depicting the hypothesized relationships that constitute the core of our proposed research model. This visual representation acts as a guiding map, outlining the complex network of relationships and interdependencies at the heart of our investigation. It highlights the pioneering combination of PLS-SEM and cutting-edge ML techniques, offering a holistic view of the determinants impacting technology adoption.

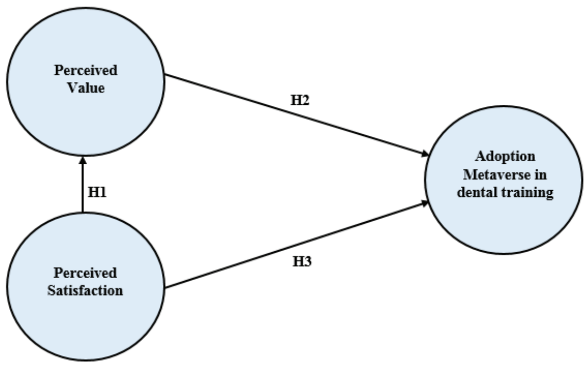

Fig. 2. Research model.

III. METHODS

From January to March 2024, data collection was executed via self-administered surveys, targeting university students from the College of Dental Medicine at the University of Sharjah. Participation was on a voluntary basis, with no monetary compensation offered to the respondents. To gather the necessary data for our analysis, we opted for a convenience sampling method. Of the 100 distributed questionnaires, 89 were duly completed and returned, resulting in an outstanding response rate of 89%. The demographic analysis of the respondents highlighted a composition of 24 males and 65 females. Notably, the vast majority, approximately 94.4%, were between the ages of 18 and 29 years, illustrating a group that is predominantly youthful and diverse in its educational pursuits, reflecting the dynamic academic engagement prevalent in the region.

IV. FINDINGS AND DISCUSSION

A. Data Analysis

This investigation harnessed the capabilities of SmartPLS version 3.2.7, a sophisticated tool designed specifically for Partial Least Squares Structural Equation Modeling (PLS-SEM) [23], to conduct its data analysis. Adopting a dual-phase evaluation strategy, the study rigorously assessed both the measurement models, to establish the constructs' reliability and validity, and the structural models, to explore the hypothesized relationships between constructs [12], [13]. The selection of PLS-SEM as the analytical tool of choice is attributed to its proficiency in revealing complex interrelations within theoretical frameworks. Unlike other methodologies that might analyze theoretical constructs in isolation [14], [15], PLS-SEM evaluates them collectively, effectively overcoming a notable limitation encountered in alternative analytical approaches. This attribute is especially beneficial for models encompassing multiple constructs and hypotheses. Moreover, PLS-SEM facilitates the simultaneous examination of measurement and structural models, offering a comprehensive analysis of the dataset [16].

PLS-SEM's adaptability to non-normal data distributions and its efficiency with smaller sample sizes render it an ideal instrument for exploratory studies aimed at theory development rather than validation. Its predictive accuracy provides dependable insights, which are crucial for making informed strategic decisions. Given these advantages, PLS-SEM is frequently chosen for investigations intended to deepen and refine theoretical frameworks [17], [18]. By leveraging PLS-SEM, this research endeavors to illuminate the intricacies of Metaverse adoption and make a significant contribution to the discourse on technology acceptance models.

B. Convergent and Discriminant validity

To ensure the integrity and reliability of the research framework, we applied Cronbach's alpha and Composite Reliability (CR) metrics for its evaluation. According to widely accepted criteria, a framework is considered reliable when both indicators exceed the threshold of 0.70 [19], underscoring the foundation of confidence and credibility in the research findings [20]. The metrics reported in Table I align with these established norms, affirming the framework's reliability.

The assessment of convergent validity, a key factor in establishing the study's validity, involved an analysis of factor loadings and the Average Variance Extracted (AVE). To achieve acceptable convergent validity, AVE values should not fall below 0.50 [20], and factor loadings are expected to be 0.70 or higher [19]. This detailed examination, covering both convergent and discriminant validity aspects, is documented comprehensively [20]. The results, as displayed in Table I, meet these critical criteria, confirming the model's convergent validity.

To evaluate the psychometric properties of the data, we focused on one critical metrics: the Fornell-Larcker criterion. An analysis presented in Table II reveals that the square roots of the Average Variance Extracted (AVE) values exceed their corresponding construct correlations, in accordance with the Fornell-Larcker criterion [21]. After a comprehensive review of the model's outcomes, no issues related to validity or reliability were identified. Consequently, the data collected is deemed both reliable and suitable for an in-depth analysis and understanding of the conceptual framework proposed.

TABLE I. CONVERGENT VALIDITY

Constructs	Items	Factor Loading	CA	CR	AVE
PS	PS1	0.857	0.866	0.918	0.788
	PS2	0.892			
	PS3	0.914			
PV	PV1	0.912	0.881	0.927	0.808
	PV2	0.899			
	PV3	0.885			
META	META1	0.926	0.859	0.934	0.876
	META2	0.946			

TABLE II. FORNELL-LARCKER SCALE

	MEAT	PS	PV
META	**0.936**		
PS	0.798	**0.888**	
PV	0.822	0.870	**0.899**

C. Hypotheses Testing

1. Hypotheses testing using PLS-SEM

The methodologies outlined were rigorously applied to scrutinize the hypotheses presented [22]–[25]. Utilizing Smart PLS to navigate the complexities of the structural equation model, we uncovered significant relationships among the various theoretical components within our framework [26]–[29]. The analysis revealed a 70.4% engagement level with the Metaverse (ME), reflecting the model's elements and highlighting its robust capacity for prediction, as illustrated in Figure 3. The examination of each data point offered further support for our hypotheses. The outcomes derived from the PLS-SEM analysis, including beta (β) coefficients, t-values, and p-values for each hypothesis, are detailed in Table III. This analysis provides empirical support, bolstering the validity of hypotheses H1, H2, and H3.

TABLE III. THE OUTPUT OF SEM

Hypotheses	Path	Path coefficient	*t*-value	*p*-value	Result
H1	PS -> PV	0.870	24.533	0.000	Supported**
H2	PV -> META	0.527	3.587	0.000	Supported**
H3	PS -> META	0.339	2.197	0.028	Supported*

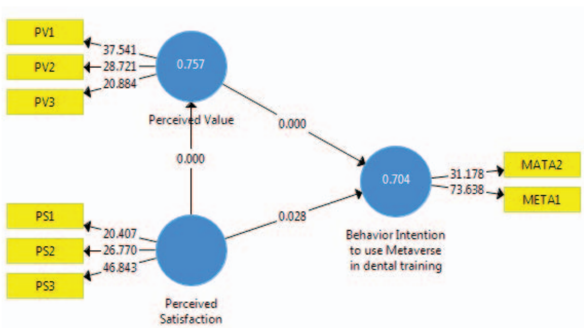

Fig. 3. Structural Model Results

2. Hypotheses testing using ML

For the evaluation of our predictive model, Weka software (version 3.8.3) was utilized, encompassing a comprehensive suite of classifiers such as BayesNet, AdaBoostM1, LWL, Logistic, J48, and OneR [30], [31]. The methodology incorporated a variety of analytical tools, including Bayesian networks, decision trees, rule-based classifiers, and neural networks, to explore the intricacies of the proposed conceptual framework using advanced machine learning and classification techniques [32].

The findings, illustrated in Figure 4, demonstrated that the J48 decision tree algorithm outperformed its counterparts in accurately predicting the relationship between perceived value (PV) and perceived satisfaction (PS), achieving an impressive prediction accuracy of 89.63%. This outcome lends robust support to Hypothesis H1.

Further analysis, as shown in Figure 5, highlighted the J48 classifier's exceptional ability in predicting user engagement with the Metaverse (META). Employing a 10-fold cross-validation method, the J48 algorithm forecasted engagement with a remarkable precision rate of 91.59%, thereby affirming Hypotheses H2 and H3. The J48 classifier showcased exemplary efficacy, evidenced by its high True Positive (TP) rate of .912, precision of .913, and recall rate of .912, marking it as the most effective tool among the evaluated classifiers for understanding user behaviors within the Metaverse.

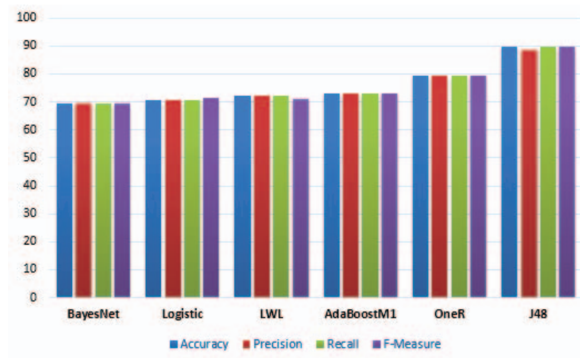

Fig. 4. PV by PS

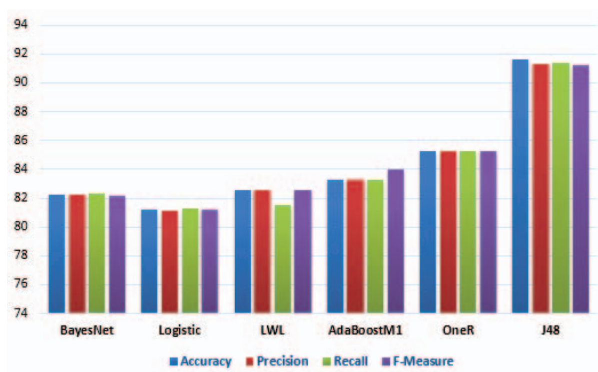

Fig. 5. META by PS, and PV

V. COCLUSION

This investigation explores the revolutionary role of the Metaverse in reshaping dental education, portraying it not merely as a technological tool but as an encompassing educational ecosystem that synergizes academic knowledge, experiential learning, and cutting-edge technological advancements. The Metaverse emerges as an innovative and potent educational platform, significantly enhancing the landscape of dental training. Our comprehensive evaluation highlights its impactful contribution to dental education, with elements like Perceived Value (PV) and Perceived Satisfaction (PS) being crucial determinants of user acceptance. However, our findings also suggest a differential impact of the evaluated factors on the adoption of the Metaverse, paving the way for more targeted development strategies to enhance its utility and reach within the dental education community.

From an academic perspective, our study leverages the analytical capabilities of Partial Least Squares Structural Equation Modeling (PLS-SEM) and Machine Learning (ML) to unravel the intricacies of our research model, marking a significant leap forward in the realm of Information Systems (IS) research. This methodological fusion, especially the application of ML algorithms to investigate the nuances of Metaverse adoption, opens new research pathways previously untapped in existing literature. Prior investigations [33]–[36] have highlighted the efficacy of PLS-SEM in validating theoretical constructs and predicting outcomes, while the predictive accuracy of ML methodologies has been lauded across diverse disciplines. Our research extends this narrative by employing advanced ML strategies, such as the J48 algorithm, to gain deeper insights into the factors influencing Metaverse adoption.

Nevertheless, the focus of our study is relatively narrow, centering on students in the Gulf region and their use of technology in education. Future research endeavors could broaden this perspective to encompass a wider demographic range, various professional fields, and different educational settings. While our current model, emphasizing pivotal factors like PV and PS, lays a solid foundation, further studies could enrich our understanding by incorporating additional variables and moderators. Such expansions would offer a more comprehensive view of the Metaverse's extensive role in dental education, contributing to its development as a premier learning platform.

References

[1] N. Stephenson, "Snowcrash. London: ROC." Penguin, 1992.

[2] J. Díaz, C. Saldaña, and C. Avila, "Virtual World as a Resource for Hybrid Education," *Int. J. Emerg. Technol. Learn.*, vol. 15, no. 15, pp. 94–109, 2020.

[3] C. Collins, "Looking to the future: Higher education in the Metaverse," *Educ. Rev.*, vol. 43, no. 5, pp. 51–63, 2008.

[4] J. B. P. Arcila, "Metaversos Para el máster iberoamericano en educación en entornos virtuales," *Etic@ net. Rev. científica electrónica Educ. y Comun. en la Soc. del Conoc.*, vol. 14, no. 2, pp. 227–248, 2014.

[5] I. V Márquez, "Metaversos y educación: Second Life como plataforma educativa," *Rev. ICONO14 Rev. científica Comun. y Tecnol. emergentes*, vol. 9, no. 2, pp. 151–166, 2011.

[6] J. Jeon and S. K. Jung, "Exploring the educational applicability of Metaverse-based platforms," 한국정보교육학회: 학술대회논문집, pp. 361–368, 2021.

[7] H. Kanematsu, Y. Fukumura, N. Ogawa, A. Okuda, R. Taguchi, and H. Nagai, "Practice and evaluation of problem based learning in Metaverse," in *EdMedia+ Innovate Learning*, 2009, pp. 2862–2870.

[8] M. Kleijnen, K. De Ruyter, and M. Wetzels, "An assessment of value creation in mobile service delivery and the moderating role of time consciousness," *J. Retail.*, vol. 83, no. 1, pp. 33–46, 2007.

[9] L. Aroean and N. Michaelidou, "Are innovative consumers emotional and prestigiously sensitive to price?," *J. Mark. Manag.*, vol. 30, no. 3–4, pp. 245–267, 2014.

[10] Y. Gao *et al.*, "Nanoceramic VO2 thermochromic smart glass: A review on progress in solution processing," *Nano Energy*, vol. 1, no. 2, pp. 221–246, 2012.

[11] W. Huang and J. W. Stokes, "MtNet: a multi-task neural network for dynamic malware classification," in *International conference on detection of intrusions and malware, and vulnerability assessment*, 2016, pp. 399–418.

[12] J. Hair, C. L. Hollingsworth, A. B. Randolph, and A. Y. L. Chong, "An updated and expanded assessment of PLS-SEM in information systems research," *Ind. Manag. Data Syst.*, vol. 117, no. 3, pp. 442–458, 2017.

[13] K. Q. Al Hamad, R. B. Al Rashdan, B. A. Al Rashdan, and F. A. Al Quran, "Effect of CAD-CAM tool deterioration on the trueness of ceramic restorations," *J. Prosthet. Dent.*, 2020.

[14] K. Q. Al Hamad, F. A. Al-Omari, and A. S. Al Hyiasat, "The taper of cast post preparation measured using innovative image processing technique," *BMC Oral Health*, vol. 10, no. 1, pp. 1–8, 2010.

[15] R. Almaiah, M.A.; Alhumaid, K.; Aldhuhoori, A.; Alnazzawi, N.; Aburayya, A.; Alfaisal, R.; Salloum, S.A.; Lutfi, A.; Al Mulhem, A.; Alkhdour, T.; Awad, A.B.; Shehab, "Factors Affecting the Adoption of Digital Information Technologies in Higher Education: An Empirical Study," *Electronics*, vol. 11, no. 3572, 2022.

[16] D. Barclay, C. Higgins, and R. Thompson, *The Partial Least Squares (pls) Approach to Casual Modeling: Personal Computer Adoption Ans Use as an Illustration*. 1995.

[17] N. Urbach and F. Ahlemann, "Structural equation modeling in information systems research using partial least squares," *J. Inf. Technol. theory Appl.*, vol. 11, no. 2, pp. 5–40, 2010.

[18] M. A. Almaiah *et al.*, "Measuring Institutions' Adoption of Artificial Intelligence Applications in Online Learning Environments: Integrating the Innovation Diffusion Theory with Technology Adoption Rate," *Electronics*, vol. 11, no. 20, p. 3291, 2022.

[19] J. F. Hair, W. C. Black Jr, B. J. Babin, and R. E. Anderson, "Multivariate Data Analysis", Pearson Prentice Hall, USA," 2010.

[20] J. F. Hair Jr, G. T. M. Hult, C. Ringle, and M. Sarstedt, *A primer on partial least squares structural equation modeling (PLS-SEM)*. Sage Publications, 2016.

[21] J. Henseler, C. M. Ringle, and M. Sarstedt, "A new criterion for assessing discriminant validity in variance-based structural equation modeling," *J. Acad. Mark. Sci.*, vol. 43, no. 1, pp. 115–135, 2015.

[22] S. A. Salloum and K. Shaalan, "Adoption of E-Book for University Students," in *International Conference on Advanced Intelligent Systems and Informatics*, 2018, pp. 481–494.

[23] R. S. Al-Maroof *et al.*, "Acceptance determinants of 5G services," *Int. J. Data Netw. Sci.*, vol. 5, no. 4, pp. 613–628, 2021.

[24] R. S. Al-Maroof *et al.*, "The effectiveness of online platforms after the pandemic: will face-to-face classes affect students' perception of their Behavioural Intention (BIU) to use online platforms?," in *Informatics*, 2021, vol. 8, no. 4, p. 83.

[25] S. A. Salloum, W. Maqableh, C. Mhamdi, B. Al Kurdi, and K. Shaalan, "Studying the Social Media Adoption by university students in the United Arab Emirates," *Int. J. Inf. Technol. Lang. Stud.*, vol. 2, no. 3, 2018.

[26] S. A. Salloum, N. M. N. AlAhbabi, M. Habes, A. Aburayya, and I. Akour, "Predicting the Intention to Use Social Media Sites: A Hybrid SEM - Machine Learning Approach," *Adv. Intell. Syst. Comput.*, vol. 1339, no. March, pp. 324–334, 2021.

[27] M. Alghizzawi, M. Habes, and S. A. Salloum, *The Relationship Between Digital Media and Marketing Medical Tourism Destinations in Jordan: Facebook Perspective*, vol. 1058. 2020.

[28] I. Akour *et al.*, "A Conceptual Model for Investigating the Effect of Privacy Concerns on E-Commerce Adoption: A Study on United Arab Emirates Consumers," *Electronics*, vol. 11, no. 22, p. 3648, 2022.

[29] R. S. Al-Maroof *et al.*, "Students' perception towards behavioral intention of audio and video teaching styles: An acceptance study," *Int. J. Data Netw. Sci.*, vol. 6, no. 2, p. 603, 2022.

[30] E. Frank *et al.*, "Weka-a machine learning workbench for data mining," in *Data mining and knowledge discovery handbook*, Springer, 2009, pp. 1269–1277.

[31] K. M. Alomari, A. Q. AlHamad, and S. Salloum, "Prediction of

the Digital Game Rating Systems based on the ESRB."

[32] I. Arpaci, "A hybrid modeling approach for predicting the educational use of mobile cloud computing services in higher education," *Comput. Human Behav.*, vol. 90, pp. 181–187, 2019.

[33] M. Alshurideh, B. Al Kurdi, S. A. Salloum, I. Arpaci, and M. Al-Emran, "Predicting the actual use of m-learning systems: a comparative approach using PLS-SEM and machine learning algorithms," *Interact. Learn. Environ.*, pp. 1–15, 2020.

[34] I. Akour, M. Alshurideh, B. Al Kurdi, A. Al Ali, and S. Salloum, "Using Machine Learning Algorithms to Predict People's Intention to Use Mobile Learning Platforms During the COVID-19 Pandemic: Machine Learning Approach," *JMIR Med. Educ.*, vol. 7, no. 1, pp. 1–17, 2021.

[35] A. Almarzouqi, A. Aburayya, and S. A. Salloum, "Prediction of User ' s Intention to use Metaverse System in Medical Education : A Hybrid SEM- ML Learning Approach," 2017.

[36] A. Aburayya and S. A. Salloum, "The Effects of Subjective Norm on the Intention to Use Social Media Networks: An Exploratory Study Using PLS-SEM and Machine Learning Approach."