Journal of Infrastructure, Policy and Development 2024, 8(9), 6232.
https://doi.org/10.24294/jipd.v8i9.6232

Article

Optimizing augmented reality adoption in higher education: A comprehensive analysis of factors impacting data management efficiency

Fanar Shwedeh[1,*], Mohamed Abdalla Nour[2], Iman Akour[2]

[1] College of Business, City University Ajman, Ajman 18484, United Arab Emirates
[2] Department of Information Systems, College of Computing and Informatics, University of Sharjah, Sharjah 27272, United Arab Emirates
*** Corresponding author:** Fanar Shwedeh, s.fanar@cu.ac.ae

CITATION

Shwedeh F, Nour MA, Akour I. (2024). Optimizing augmented reality adoption in higher education: A comprehensive analysis of factors impacting data management efficiency. Journal of Infrastructure, Policy and Development. 8(9): 6232. https://doi.org/10.24294/jipd.v8i9.6232

ARTICLE INFO

Received: 6 May 2024
Accepted: 17 June 2024
Available online: 6 September 2024

Abstract: This study explores the complex dynamics of handling augmented reality (AR) data in higher education in the United Arab Emirates (UAE). Although there is a growing interest in incorporating augmented reality (AR) to improve learning experiences, there are still issues in efficiently managing the data produced by these apps. This study attempts to understand the elements that affect AR data management by examining the relationship between the investigated variables: faculty readiness, technological limits, financial constraint, and student engagement on data management in higher education institutions in the UAE, building on earlier research that has identified these problems. The research analyzes financial constraints, technological infrastructure, and faculty preparation to understand their impact on AR data management. The study collected detailed empirical data on AR data management in UAE higher education environments using a quantitative research methods approach, surveys. The reasons for choosing this research method include cost-effectiveness, flexibility in questionnaire design, anonymity and confidentiality involved in the chosen methods. The results of this study are expected to enhance academic discourse by highlighting the obstacles and remedies to improving the efficiency of AR technology data management at higher education institutions. The findings are expected to enlighten decision-making in higher education institutions on maximizing AR technology's benefits for improved learning outcomes.

Keywords: augmented reality; faculty readiness; technological infrastructure; financial constraints; data management

1. Introduction

In the technologically advanced United Arab Emirates (UAE), there has been an upsurge in using augmented reality (AR) to transform data administration and enhance the learning experience in higher education.

As studies such as those by Eppard et al. (2019), Faqih and Jaradat (2021), Xanthidis et al. (2020), demonstrate AR is gaining tangible traction in higher education in the UAE. However, despite advancements in integrating AR in teaching and learning, a substantial obstacle remains in efficiently managing data for AR applications. This difficulty is highlighted in prior studies by Abad-Segura et al. (2020) and Munnerley et al. (2014), which emphasize the necessity for further investigation to establish resilient approaches for the smooth administration of AR data. Although previous research has provided insights into attempts to incorporate AR into education, the effective management of AR-generated data remains challenging, particularly in a technologically advanced environment such as the UAE. Acknowledging and confronting this obstacle is crucial, given that various elements, including faculty readiness, resource limitations, institutional commitment, and technological infrastructure, all influence the administration of AR data. Therefore, the goal of this research was to investigate the critical factors, including financial limitations, technological infrastructure, and faculty preparedness, that influence the effectiveness of AR data management. By doing so, it aims to gain a comprehensive understanding of how these factors interact and ultimately improve the efficacy of AR in the context of higher education data management in the UAE.

While several recent studies have made some contributions in this regard by examining the acceptance of the AR technology or its integration into the education systems of higher education institutions (Faqih and Jaradat, 2021; Matsika and Zhou, 2021; Xanthidis et al., 2020), or identifying challenges facing AR data management (Abad-Segura et al., 2020; Munnerley et al., 2014), there is very little research that specifically focuses on the factors that influence the data management aspect of such integration. In particular, the current research departs from prior literature by examine the content (data) generated by the AR technology as a critical component underpinning its operational success. Effectively managing such AR data, therefore, is paramount to the ultimate success of any AR integration in the educational systems. Consequently, this research investigates the factors that influence the successful management of such data. Our objective in conducting such inquiry is to provide significant contributions to the literature in understanding how to manage these factors and accordingly how to optimize the use of AR in data management practices within higher education. To the authors' best knowledge, this current research is thus distinctively unique in its research focus and contributions.

The rest of this paper is organized as follows. First, we provide a theoretical background and relevant literature review, followed by a section that develops the research model and hypotheses. The following section discusses the research methodology, followed by the empirical results and analyses. We next provide a discussion and implications of our empirical results, followed by the final section with the conclusion, limitations, and future research directions.

2. Literature review

2.1. Overview of augmented reality in higher education

AR entails superimposing digital data onto the real world, resulting in an engaging and interactive experience for users (Ali, 2024; Lee et al., 2024). AR apps have been created in higher education to enhance conventional teaching approaches, offering students a comprehensive and captivating learning encounter. Incorporating AR in education has been thoroughly examined in prior literature (Li and Liu, 2023; Lu and Liu, 2015; Snyde et al., 2023), and its prospective uses are still developing (Delello et al., 2015).

An essential feature of AR in higher education is its capacity to connect academic concepts with practical applications. AR enhances comprehension of intricate topics by overlaying digital aspects onto the physical environment, rendering abstract notions concrete and easily accessible. AR applications are versatile and can be applied across various fields, including science, engineering, humanities, and arts.

2.2. Significance of AR in enhancing the learning experience

The importance of AR in higher education stems from its profound influence on learning. Xanthidis et al. (2020) argue that AR improves learning by offering interactive and immersive material, encouraging active student participation (Rodríguez-Abad et al., 2023; Stalheim and Somby, 2024; Udeozor et al., 2023). AR surpasses conventional instructional techniques by providing a customized and adaptable approach to education (Calik et al., 2024).

Furthermore, AR applications enhance the ability to retain and understand information. Liarokapis and Anderson (2010) and Munnerley et al. (2014) contend that the use of AR with its visual and interactive features enhances the retention of knowledge, hence making it a valuable tool for both theoretical comprehension and practical experimentation (AlQallaf et al., 2024; Christopoulos et al., 2024; Wong et al., 2024).

By actively manipulating digital information superimposed on real-world objects, students engage in a dynamic and memorable learning experience.

Moreover, Martin-Gutierrez et al. (2015) and Yuen et al. (2011) emphasize the capacity of AR to facilitate collaborative and self-directed learning. AR enables students to engage with virtual content collaboratively, promoting the development of teamwork and critical thinking abilities. This collaborative method aligns with modern educational paradigms that value learning centered around the learner and based on real-life experiences (Farhi, 2024).

Srivastava (2016) emphasized the need for AR in electrical engineering laboratories due to students feeling frustrated because of disconnects between the practice and theory and procedural difficulties in the laboratory. The author proposed two prototypes: an AR-based circuit-building application, a lab manual, and an intelligent breadboard.

2.3. Growing interest in AR technologies in the UAE

The growing fascination with AR technologies in the UAE is demonstrated by a comprehensive examination of academic literature. Xanthidis et al. (2020) thoroughly analyze the status of AR in higher education, highlighting its capacity for profound change. Their findings, showcased at the Seventh International Conference on Information Technology Trends, establish a basis for comprehending the UAE's dedication to incorporating AR into its educational framework. Visvizi et al. (2019) examine the impact of institutional dynamics on integrating AR in higher education institutions, emphasizing the crucial role of management and administration in this process. Abad-Segura et al. (2020) provide an additional viewpoint by examining the sustainability of educational technologies. They present a comprehensive assessment of the long-term viability and impact of AR technologies in education, which is an essential factor for policymakers in the UAE to consider.

Transitioning from theoretical concepts to real-world implementations, Munnerley et al. (2014) explore the specific uses of AR in higher education, offering practical knowledge customized for the distinct circumstances of the UAE. The UAE's dedication to utilizing the capabilities of AR is further demonstrated in Eppard et al.'s (2019) case study, which focuses specifically on mobile learning tools that incorporate AR applications. This case study provides significant insights for educators and policymakers navigating AR integration into the mobile learning environment. Moreover, Xanthidis et al. (2020) investigated the Triple Helix model, highlighting the importance of collaboration between academia, industry, and government. Their study focuses on exploring the potential of this paradigm for the future. The UAE's dedication to promoting innovation through partnerships involving several stakeholders is demonstrated by this collaborative approach, which aligns with the changing landscape of AR in higher education. Ultimately, the UAE's increasing fascination with AR technologies is demonstrated by a bold and multi-faceted undertaking, encompassing theoretical principles, practical implementations, and a shared vision for the future.

2.4. Challenges of AR technology adoption in education institutions

Abad-Segura et al. (2020) and Munnerley et al. (2014) have identified a significant challenge in AR data management: the complex integration of AR tools. Despite advancements, integrating AR systems into higher education poses challenges primarily due to data management difficulties (Papaevangelou et al., 2024).

Technical difficulties, inadequate organizational readiness, and the absence of standardized frameworks contribute to the challenges that Abad-Segura (2020) and Munnerley et al. (2014) identified. Abad-Segura et al. (2020) and Munnerley et al. (2014) emphasized the need to tackle technological obstacles and sustainability challenges while implementing AR in higher education. Alzahrani (2020) conducted a systematic review of the benefits and challenges of AR in the context of e-learning and their findings include cognitive and information overload, a lack of prior experience with the technology, opposition from teachers, expensive and complex technology, and technical difficulties like poor connectivity.

The challenges associated with incorporating AR solutions highlight the intricacy of data management practices in higher education institutions. Addressing the challenges of effective AR adoption in higher education requires conducting a detailed examination of the relevant factors to develop efficient and effective AR deployment strategies for managing data in higher education. This is essential because of the complex factors such as technological infrastructure, faculty readiness, student engagement, and financial availability constraints that prevent the smooth integration of AR into higher educational systems (Alkhasawneh, 2023; Delello et al., 2015; Xanthidis et al., 2020). Gaining a comprehensive understanding of these subtleties is crucial for developing efficient and focused strategies, mitigating the barriers that impede the integration of AR tools, and enhancing the utility of AR in managing data in higher education.

2.5. Data management application adoption among higher education institutions in the UAE

Data management is prioritized in the UAE, particularly in higher education and AR technologies. Jarrah and Alkhasawneh (2023) and Xanthidis et al. (2020) demonstrate the increasing popularity of AR and emphasize the importance of effective data management for its successful implementation in the field of education. According to these authors, education in the UAE is influenced by advanced technology, including AR. The integration of AR has transformed higher education in the UAE, providing students with advanced and state-of-the-art study opportunities.

Thus, robust AR data management systems are essential for enhancing higher education in the UAE. Proactive measures must be taken to solve AR data management risks due to the rapid use of technology. To remain at the forefront of educational innovation, keep pace with global breakthroughs, and efficiently integrate AR solutions for data management in UAE higher education, it is crucial to address these problems.

2.6. Advances in technology and its impact on AR adoption in the UAE's higher education landscape

Several recent scholarly investigations have made substantial contributions to the discourse surrounding the incorporation of AR in higher education, illuminating the complex aspects of its implementation. The integration of AR in higher education is thoroughly examined in recent research conducted by Eppard et al. (2019), Faqih and Jaradat (2021), and Xanthidis et al. (2020). Xanthidis et al. (2020) provide valuable perspectives on AR adoption's present status and prospects, while Faqih and Jaradat contribute by combining the Task-Technology Fit Model (TTF) and the Unified Theory of Acceptance and Use of Technology (UTAUT2) theories to comprehend AR technology acceptance better. The case study conducted by Eppard et al. (2021) focuses explicitly on the UAE, providing a practical perspective on the integration of AR into the country's higher education systems.

Meanwhile, the significance of AR in the UAE's higher education sector is apparent due to the country's deliberate emphasis on technical progress, as emphasized by Jarrah and Alkhasawneh (2023). This strategic interest aligns with the overall dedication to innovation and technological superiority, highlighting the importance of AR as a powerful instrument for transforming education. Xanthidis et al. (2020) emphasize that technological improvements underscore the significance of AR in maintaining the dynamism and alignment of higher education with the global digital ecosystem. The results demonstrate that technical advancements influence the significance of AR and emphasize the mutually beneficial connection between technological progress and the use of AR in higher education institutions in the UAE. Ahmed (2020) developed a strategy for integrating AR-enabled Building Information Modeling (BIM) techniques into a traditional teaching approach for a core building construction course in the UAE University's (UAEU) Architectural Engineering Undergraduate Program. This course is now delivered entirely digitally and through immersive remote learning.

3. Research framework and hypotheses

3.1. Relationship between technology limitations and effective data management using AR

Various academic studies on infrastructure platforms and the interplay of AR with other emerging technologies indicate that the administration of AR data is constrained by technical infrastructure. Kshniakin et al. (2010) conducted research on the development and dissemination of AR and virtual reality (VR) solutions utilizing an infrastructure platform. The study emphasizes the significance of a robust technological framework for developing and disseminating AR content. This underscores the necessity of a resilient infrastructure to handle AR data efficiently.

Research on intelligent urban areas involving the combination of Building Information Modeling (BIM), AR, and VR exposes the issues related to technology infrastructure. Gharaibeh et al. (2017) observed the intricate relationship between infrastructure functionality and AR deployment. Salem et al. (2020) highlight the significance of employing Building Information Modeling (BIM) and virtual reality/augmented reality (VR/AR) technologies in asset management, starting from the beginning of a project. Carneiro et al. (2018) investigate the potential enhancements that BIM, GIS, Internet of Things (IoT), and AR/VR could bring to the maintenance and management of intelligent road networks. These findings suggest that a contemporary, interconnected technological framework is necessary to oversee AR data and guarantee its successful implementation in diverse environments.

3.2. Relationship between faculty readiness and effective data management using AR

The preparedness of the faculty plays a crucial role in determining the effective implementation of AR in higher education. Al-Araibi et al. (2019) stress the importance of the technological elements contributing to e-learning preparation. They underline that faculty members must have many technology capabilities beyond basic technical skills. Almulla's (2022) study on factors impacting students' preparedness indirectly emphasizes the vital role of teachers in leading students through inventive instructional approaches, such as those that use AR. In addition, exploration of the technical readiness level among faculty members, highlighting the importance of their technology preparedness to adopt AR successfully. Alahmari's (2023) study focuses on the factors influencing staff's willingness to adopt AR, emphasizing the significance of a favorable attitude among faculty members. Finally, Petrovych et al. (2023) investigate the motivational preparedness of prospective educators, providing valuable insights into the factors that may impact instructors' willingness to integrate AR and gamification into their teaching approaches.

To summarize, the literature study emphasizes that faculty readiness is a complex concept that includes technological skills, adaptability of teaching methods, and a favorable attitude towards innovation. Ensuring faculty preparation is crucial for creating a dynamic and transformative learning environment as higher education institutions use AR technologies.

3.3. Relationship between financial constraints and effective data management using AR

The impact of financial limitations on implementing AR in higher education is substantial, as supported by studies conducted across multiple disciplines. In their research, Matsika and Zhou (2021) investigate the determinants influencing the acceptance and utilization of augmented virtual reality (AVR) technology in higher and tertiary education. Their study explores the financial factors organizations encounter while adopting AR technology, revealing the practical difficulties connected with limited financial resources.

Chandra and Kumar (2018) investigate the factors that affect organizations' adoption of AR in e-commerce. Their findings may also apply to the higher education sector. The financial ramifications of incorporating AR are expected to be a pivotal factor influencing the decision-making process in educational institutions. Moreover, Govindan et al. (2023) and Moro et al. (2017) highlight the efficacy of virtual and Augmented Reality in health sciences and the implementation of blockchain technology, respectively. Although not explicitly centred on education, these studies implicitly emphasize the financial factors that go beyond different fields and impact judgments on adopting technology.

In addition, Sosnovska and Zhytar (2018) contribute to the discussion by analyzing the financial architecture as the foundation of financial security in businesses. While not exclusively focused on AR in education, this research can provide significant insights into the financial frameworks and safety precautions institutions must consider while using cutting-edge technologies. These studies collectively demonstrate the challenging adoption of AR in higher education due to financial constraints. This underscores the significance of meticulous preparation and efficient deployment of funds and resources to guarantee the seamless integration of AR in higher education.

3.4. Relationship between students' engagements and effective data management using AR

The effect of student engagement on managing AR data is examined through a range of research demonstrating the connection between active student involvement and effective handling of AR-generated information. Soltis et al. (2020) introduce a new technique for assessing student engagement in an AR sandbox, illustrating the influence of active involvement with AR tools on the overall learning process. Similarly, Murrell et al. (2020) examined meteorology AR, a mobile AR software designed to enhance student engagement and promote active learning in a large lecture setting. The authors emphasize the positive correlations between participation and the use of AR technology.

The study by Drljević et al. (2022) provides further insights into student engagement through AR in elementary school environments. Their research centers on engagement in AR learning experiences and gives insight into the intricacies of student interaction with augmented content. This comprehensive inquiry enhances our comprehension of how student participation impacts the utilization and administration of AR data.

Kamat and Nasnodkar (2021) empirically investigate the influence of 3D printing on many aspects of student engagement, expanding the focus on Science, Technology, Engineering and Mathematics (STEM) education. Although not explicitly focusing on AR, their research offers valuable insights into the impact of immersive technologies on student engagement in educational environments. These studies emphasize student engagement's crucial role in influencing AR data management's effectiveness. They stress the significance of active participation in maximizing the advantages of augmented learning experiences.

3.5. The unified theory of acceptance and use of technology (UTAUT2)

When examining the integration of AR in higher education through the lens of the Unified Theory of Acceptance and Use of Technology (UTAUT2), several key factors are considered: social influence, facilitating conditions, hedonic motivation, price value, and habit (Farhi, 2024; Venkatesh et al., 2012). The dependent variable is the effectiveness of using AR for data management in higher education. The selected independent variables are technical infrastructure (Xanthidis et al., 2020), faculty preparedness (Faqih and Jaradat, 2021), student involvement (Eppard et al., 2019), and budgetary limitations (Abad-Segura et al., 2020). Xanthidis et al. (2020) provide significant insights on the significance of technical infrastructure. Faqih and Jaradat (2021) contribute to our understanding of faculty preparedness. Eppard et al. (2019) emphasize the importance of student engagement. Abad-Segura et al. (2020) shed light on the budgetary constraints that exist in the field of educational technology. This summary aligns with the UAE's strategic focus, as evidenced by the growing interest in AR technologies and the urgent need to develop robust methods for incorporating AR into data management in higher education (Jarrah and Alkhasawneh, 2023; Xanthidis et al., 2020). By integrating UTAUT2 and the results from this research, a cohesive framework is built to comprehensively understand and resolve the challenges and opportunities associated with implementing AR in higher education in the UAE. This research investigates if there is a significant influence of faculty readiness on data management, if the financial constraints significantly influence data management, if there is a significant relationship between students' engagement and data management and if technology limitation has a significant influence on data management. Based on the previous research questions the following research **Figure 1** is the research framework proposed in this study.

Given the proposed research hypotheses, the research framework is illustrated in **Figure 1**.

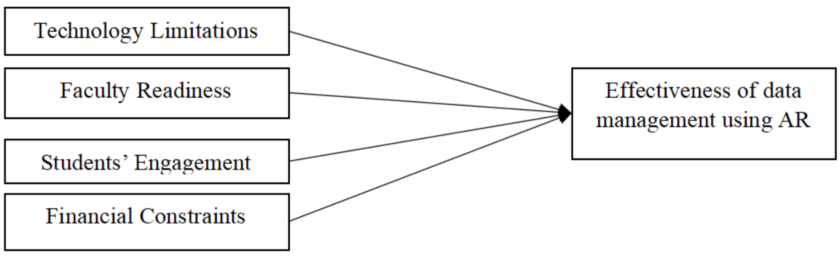

Figure 1. Research framework.

3.6. Research hypotheses

As evidenced by the reviewed literature and based on the research questions the following hypotheses were developed:

H_1: There is a significant relationship between faculty readiness and effective data management using AR.

H_2: Financial constraints have significant effects on effective data management using AR.

H_3: Students' engagement significantly influences effective data management using AR

H_4: Technology limitations significantly influence effective data management using AR.

4. Research methodology

A quantitative research approach is employed to assess the structural relationships between the identified exogenous variables: technology limitations, faculty readiness, students' engagements, and financial constraints on data management effectiveness using AR technologies. Consequently, a survey research approach will be used, as referred in the Appendix, where sets of predesigned questionnaires will be distributed to identified target samples in the UAE. The following block diagram in **Figure 2**. explains the research methods and research process sequences.

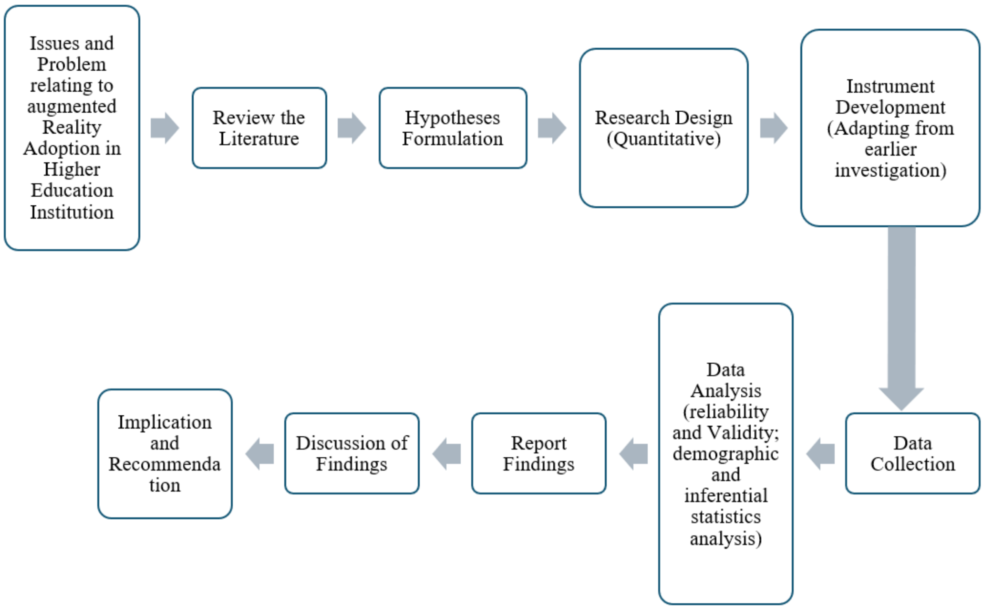

Figure 2. Block diagram of research design and execution.

The target samples are stakeholders in higher education institutions in the UAE. These include the students, academic and non-academic staff, the management, and directors. A multistage sampling technique was employed where both non-probabilistic (cluster) and probabilistic sampling techniques (simple random sampling) were applied in sample size selections (Altmann, 1974; Creswell, 2009; Etikan et al., 2016). Furthermore, since the target respondents' population is infinite, we employ the power analysis tool to estimate the needed sample size (Suresh and Chandrashekara, 2012). According to Erdfelder et al. (1996), the power analysis tool, specifically G*Power. After setting the following parameters, the test family to *F*-

test, statistical test to linear multiple regression fixed model, r^2 deviated from zero, and the number of predictors to be the number of exogenous variables (independent variables which are four {4}); the G*power tool estimated the minimum sample size to be 129. However, to limit the influence of Type I and Type II errors, we collected data from respondents; 300 responses were collected over four (4) months across the UAE.

The instrument used in this investigation was measured on a 5-point Likert scale, and the items were adapted from earlier investigations. For example, six (6) items measuring technology limitations were adapted from studies that include Eppard et al. (2019), Faqih and Jaradat (2021), Jarrah and Alkhasawneh (2023), Kshniakin et al. (2021) and Xanthidis et al. (2020). Also, five (5) items measuring faculty readiness were adapted from the studies of Alahmari (2023), Almulla (2022), Al-Araibi et al. (2019), and Drljević et al. (2022). Furthermore, five items measuring financial constraints, six (6) items measuring data management, and six (6) items measuring students' engagements were adapted from studies that include Govindan et al. (2023), Kamat and Nasnodkar (2021), Matsika and Zhou (2021), Moro et al. (2017), Murrell et al. (2020), Chandra and Kumar (2018), Soltis et al. (2020) and Sosnovska and Zhytar (2018).

Statistical analysis was performed using the partial least structural equation modelling (SEM) technique, and statistical significance for all tests was set at the 95% level (α = 0.05). We employed the partial least squares structural equation modeling (PLS-SEM) analysis tool to analyze the data collected from the respondents who were knowledgeable about data management in higher education in the UAE. These include IT professionals, faculty members, university administrators, Information and Communications Technology (ICT) lecturers, and students.

5. Findings and discussions

5.1. Demographic analysis

We use the Statistical Package for Social Sciences (SPSS) frequency distribution to check the data demographic characteristics. The result is presented in **Table 1**.

Table 1 reveals the demographic information for the surveyed respondents. The findings show that most survey participants are male respondents with 73.33% (220), followed by female counterparts with 26.67% (80) respondents. Additionally, we examined the respondents by investigating their job roles. The findings show that most of the respondents are students who are AR users, with 43.34% (130), followed by faculty members who are among the end users, with 26.67% (80) respondents. Furthermore, IT professionals and university administrators were observed to have the least respondents, having 8.33% (25) respondents each, followed by the last variable examined in this study, ICT lecturers having 13.33% (40) respondents.

Table 1. Demographic data.

Factors	Sample (*n*)	Percentage
Gender		
Female	80	26.67
Male	220	73.33
Total	300	100
Job responsibility		
IT professionals	25	8.33
Faculty members	80	26.67
University administrators	25	8.33
ICT lecturers	40	13.33
Students	130	43.34
Total	300	100

5.2. Hypotheses testing

However, before testing the proposed hypotheses in this investigation, we ensured that our measurement model had adequate properties and satisfied the requirements of the PLS-SEM analytical technique. These include the requirement that the average variance extracted (AVE) value is greater than 0.5, composite reliability is greater than 0.7, and item loading(s) is greater than 0.6 but less than 0.95According to Lai et al. (2006), any item with loadings greater than 0.95 is considered redundant. In sum, these conditions are the construct and convergent validity. The output for this step is presented in **Figure 3** and **Table 2**. Moreover, to achieve the desired AVE for the construct technology limitation, two items (tl5 and tl6) were eliminated from the model because they had lower item loadings.

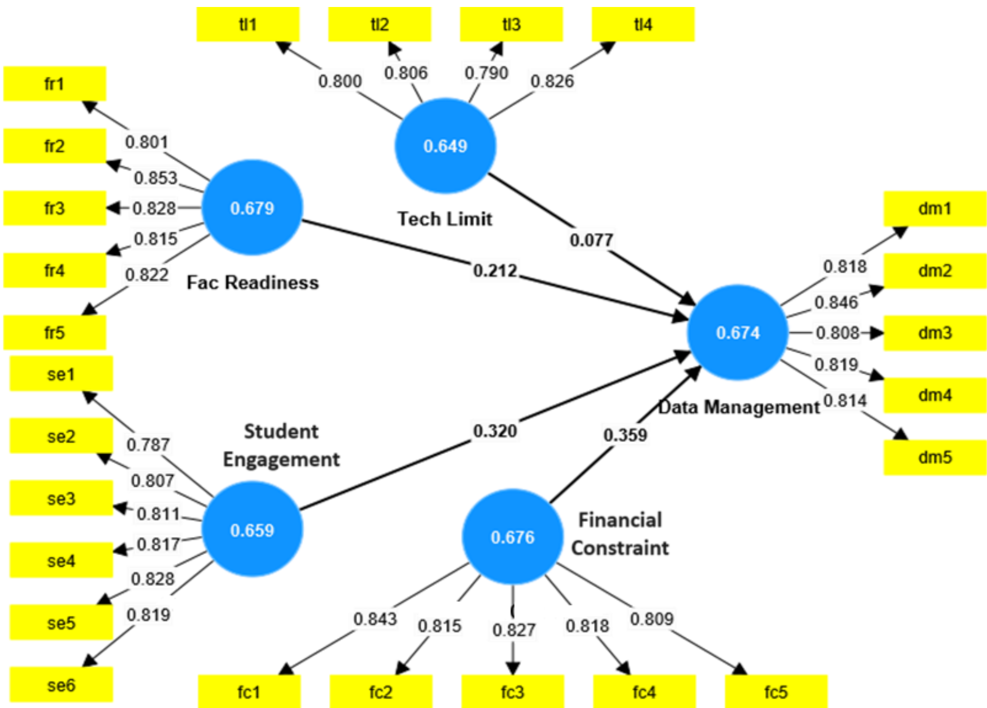

Figure 3. Measurement model.

Table 2. Item loadings, Composite Reliability (CR), AVE and discriminant validity.

Construct	Item	Item loadings	CR	AVE	Discriminant validity
Data management	dm1	0.818	0.879	0.674	YES
	dm2	0.846			
	dm3	0.808			
	dm4	0.819			
	dm5	0.814			
Faculty readiness	fr1	0.801	0.882	0.679	YES
	fr2	0.853			
	fr3	0.828			
	fr4	0.815			
	fr5	0.822			
Financial constraint	fc1	0.843	0.88	0.676	YES
	fc2	0.815			
	fc3	0.827			
	fc4	0.818			
	fc5	0.809			
Student's engagement	se1	0.787	0.897	0.659	YES
	se2	0.807			
	se3	0.811			
	se4	0.817			
	se5	0.828			
	se6	0.819			
Tech limit	tl1	0.800	0.821	0.649	YES
	tl2	0.806			
	tl3	0.790			
	tl4	0.826			

As evidenced in **Table 2**, the item loadings are all less than 0.95, the AVE is greater than 0.5, and the composite reliability is greater than the postulated value of 0.7. Given this, we conclude that the model's convergent validity is achieved.

Table 3. HTMT matrix (discriminant validity).

Construct	Data management	Fac readiness	Fin. constraint	Student's engagement
Fac readiness	0.592			
Financial constraint	0.014	0.011		
Student's engagement	0.498	0.293	0.6001	
Tech limit	0.69	0.6904	0.207	0.704

Furthermore, we assessed the data discriminant validity using Heterotrait Monotrait (HTMT) correlation. Although several studies assess data discriminant validity using the Fornel Larcker criterion and HTMT, a study by Henseler et al. (2018) suggests using HTMT because the Fornel Larcker Criterion lacks empirical support. According to Hensler (2017), the HTMT correlation value must be less than

0.9 before such a model could be assumed to have achieved discriminant validity. This is presented in **Table 3**.

Additionally, before examining the significant relationship between the variables under investigation, we assessed the possible existence of multicollinearity issues among the investigated constructs using the variance inflated factor (VIF). De Vaus (2002) and Tabachnick and Fidell (2007) described a strong correlation between two or more independent constructs as multicollinearity. When there is a high correlation between two or more constructs, these constructs are redundant, as they measure the same thing. Hence, when such a situation occurs, the variance between such variables is reduced, which increases prediction accuracies. Given this, the study of Rogerson (2001) suggests that the VIF value should be less than 5. In this investigation, the VIF values for all the constructs are less than the maximum threshold Rogerson (2001) suggested. The VIF values are presented in **Table 4**.

Table 4. VIF values.

Construct	Data management
Faculty readiness	3.15
Financial constraint	1.497
Student's engagement	3.222
Tech limit	4.813

Based on the VIF values in **Table 4** above, we conclude that the data is accessible from multicollinearity issues; thus, we assess the significant relationships between variables under investigation. The hypotheses testing is done by examining the structural model. The diagram output is presented in **Figure 4** and **Table 5**.

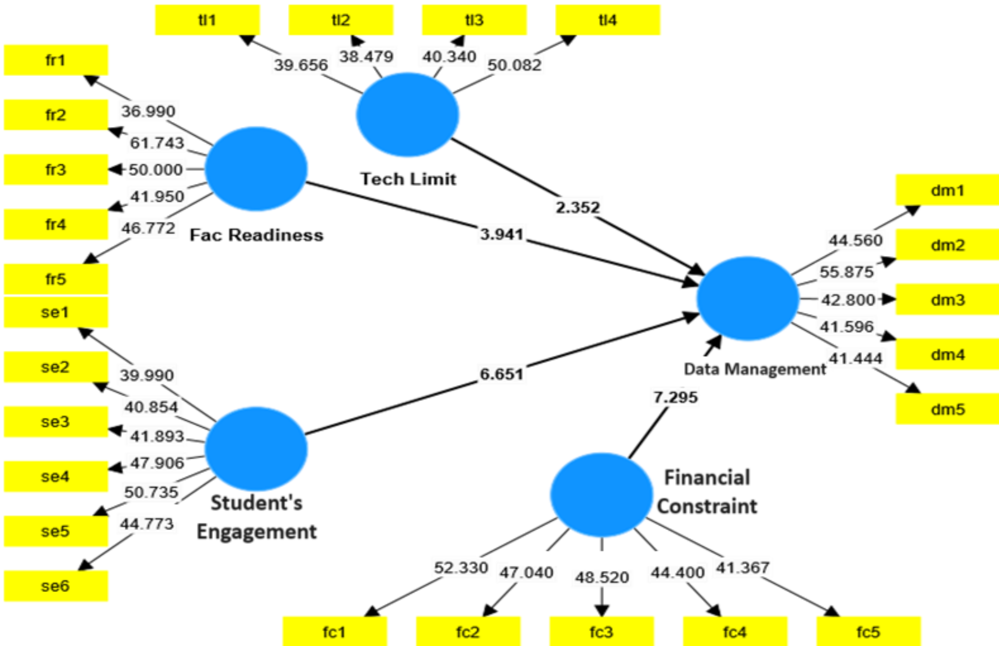

Figure 4. Structural model assessment.

Table 5. Hypotheses testing.

Hypothesis	Relationship	*β*	STDEV	*T*-stat	*P* values
H_1	Faculty readiness → data management	0.212	0.054	3.941	0
H_2	Financial constraint → data management	0.359	0.049	7.295	0
H_3	Student's engagement → data management	0.32	0.048	6.651	0
H_4	Tech limit → data management	0.077	0.033	2.352	0.019

Using the SEM analysis tool, the settings were left at default, at a 95% confidence interval and 5000 subsamples.

This investigation's first hypothesis (H_1) posits a significant relationship between faculty readiness and data management. Using SEM analysis tool to analyze the collected data, the findings reveal that the respondents believed there is a significant relationship between faculty readiness and data management in higher education in the UAE having ($\beta = 0.212$, *t*-value = 3.941), $p < 0.05$. The result in this regard suggests a positive significant relationship between faculty readiness and the effectiveness of data management when AR technology is adopted. The results indicate that the implementation of AR technology in higher education establishments is significantly and positively correlated with the efficiencies of data management (Ahmed, 2020; Abad-Segura et al., 2020; Xanthidis et al., 2020). This is consistent with prior studies that have underscored the significance of technical proficiency, faculty readiness, and motivation in facilitating effective technology integration in academic environments (Al-araibi et al., 2019). Through the validation of this correlation, this research emphasizes the critical significance of faculty preparedness in harnessing AR technology to improve data management procedures. As a result, it contributes to the broader comprehension of the elements that impact technology adoption in education.

Similarly, the result of the second hypothesis shows that the respondents believe there is a significant relationship between financial constraints and data management effectiveness during the adoption of AR technology in the higher education institutions in the UAE, having ($\beta = 0.359$, *t*-value = 7.295), $p < 0.05$. Accordingly, H_2 is accepted. According to prior research, financial constraints and data administration effectiveness during the implementation of AR technology in higher education institutions are significantly correlated (Chandra and Kumar, 2018; Matsika and Zhou, 2021). This discovery highlights the significance of financial resources in determining the success and efficiency of data management systems that utilize AR. This statement questions the prevailing belief that data management issues can be resolved solely through technological progress. It emphasizes the necessity for sufficient financial backing to maximize the use of AR in educational settings.

Likewise, the third hypothesis (H_3) in this study upholds the argument that students' engagement significantly influences data management efficiencies when AR technology is adopted in higher education institutions in the UAE, having (β = 0.32, *t*-value = 6.651), $p < 0.05$. Therefore, we accept H_3 as well. The research findings validate a significant relationship between student engagement level and data management efficiency in higher education institutions that implemented AR technology (Alzahrani, 2020; Drljević et al., 2022; Soltis et al., 2020). This discovery unearths the significance of student engagement and proactive participation in promoting efficient data management methodologies. This is consistent with previous studies, which have found that AR technology can enhance student motivation, collaboration, and knowledge retention by facilitating engaging learning experiences (Kamat and Nasnodkar, 2021; Murrell et al., 202).

Moreover, the result from the fourth hypothesis in this investigation presents a significant relationship between technology limitation and data management efficiency when AR technologies are implemented in the higher education institutions in the UAE having ($\beta = 0.077$, t-value = 2.352), $p < 0.05$; hence, H_4 is accepted. The study establishes a significant relationship between technological constraints and data management efficiencies when integrating AR technologies in higher education settings. This discovery emphasizes the difficulties caused by technology infrastructure limitations in improving AR-based data management systems. It highlights the need to overcome technological obstacles and invest in infrastructure development to guarantee the efficient use of AR technology for data management.

The findings of this study are consistent with prior studies regarding the significant role of each of the four investigated variables—Faculty readiness, financial constraints, student engagement, and technology limitations. However, the emphasis in prior studies has been invariably on AR acceptance and implementation (Chandra and Kumar, 2018; Matsika and Zhou, 2021), AR integration (Al-araibi et al., 2019), or student motivation and knowledge retention (Kamat and Nasnodkar, 2021; Murrell et al., 2020). The current study is unique in examining the influence of these variables on the effectiveness of AR data management.

6. Theoretical and practical contributions

The research findings offer useful insights into the aspects that influence the effective use of data management using AR in higher education, both theoretically and practically. The study enhances theoretical knowledge and provides practical suggestions for educational implementation, contributing to the continuous endeavor to utilize technology for improving teaching, learning, and administrative procedures in higher education institutions.

6.1. Theoretical contributions

The paper proposes educational technology adoption theories. Empirically confirming the linkages between faculty readiness, financial constraints, student engagement, technology limitations and higher education data management utilizing AR extends existing theoretical frameworks. This empirical validation reinforces the Technology-Organization-Environment (TOE) model and the Unified Theory of Acceptance and Use of Technology (UTAUT) by illustrating how these factors affect AR technology uptake (Chandra and Kumar, 2018; Faqih and Jaradat, 2021). Second, the study uses readiness, organizational learning, and engagement theories. This research examines theoretical interactions to explain the complex dynamics of technology integration in education. Therefore, the study's theoretical contributions corroborate and reinforce existing educational technology adoption research.

Moreover, through an analysis of the complex relationship between a range of determinants impacting the effectiveness of data management in the context of the adoption of AR technology, this research incorporates knowledge from several theoretical frameworks, including engagement theory, organizational learning theory, and preparedness theory. By adopting an interdisciplinary methodology, the research becomes more comprehensive and offers a more holistic comprehension of the intricate dynamics associated with integrating technology in education (Al-araibi et al., 2019; Kamat and Nasnodkar, 2021).

6.2. Practical contribution

The study's results have significant practical implications for educational practitioners, policymakers, and institutional leaders interested in improving data administration in higher education through the use of AR technology. These insights are invaluable. The research offers practical recommendations for decision-making by empirically identifying crucial determinants of AR adoption and effectiveness in data management, including faculty readiness, financial constraints, student engagement, and technology limitations (Gharaibeh et al., 2017; Matsika and Zhou, 2021). For example, academic establishments can use these discoveries to guide resource allocation strategies. Specifically, they can allocate funds towards initiatives such as software development, infrastructure improvement, and faculty training to surmount technological obstacles and bolster data management capabilities.

Furthermore, by designing AR learning experiences that promote active involvement or engagement, collaboration, and more profound involvement with course material, educators can apply the knowledge gained regarding the significance of student engagement to enhance learning outcomes (Murrell et al., 2020; Soltis et al., 2020). The research's practical implications offer institutions guidance on navigating the intricacies of integrating AR technology. This empowers them to efficiently utilize the technology's capabilities to improve data management procedures and facilitate student learning within the context of higher education.

The findings of this study have practical implications that offer actionable guidance to educational practitioners. This aids in making informed decisions concerning the allocation of resources and pedagogical practices. In conclusion, the research provides academic institutions with a strategic guide for efficiently integrating AR technology. This includes improving data management procedures, facilitating student learning, and driving advancements in educational practices in the UAE and globally

7. Conclusion and limitations

To sum it up, this research highlights the critical significance of various elements—faculty preparedness, financial restrictions, student involvement, and technological inadequacies—in shaping the efficacy of AR data administration in UAE higher education establishments. More specifically, all the four examined variables are shown to have significant influence on the effectiveness of the AR data management. Thus, through the empirical validation of these relationships, the research expands upon established theoretical frameworks, thereby providing a more holistic comprehension of the dynamics surrounding technology adoption.

Despite this study's unearthing of important contributions by revealing the significant influence of crucial variables that influence efficient data management in the UAE's higher education institutions, some essential limitations include cross-sectional design, limited sample size and limited investigated variables. Considering these, future studies might attempt to examine the following: conducting longitudinal studies, adopting a qualitative investigation and a triangulation research approach to reveal the intricacies not captured in the present investigation. Also, comparative studies with other emerging technologies offer nuanced perspectives that could be adopted. Furthermore, cross-cultural studies that unearth the influence of culture might as well be considered and expand the sample size.

Author contributions: Conceptualization, FS and MAN; methodology, FS and MAN; software, FS; validation, FS, MAN and IA; formal analysis, FS and MAN; investigation, FS and MAN; resources, IA; data curation, MAN; writing—original draft preparation, FS; writing—review and editing, MAN and IA; visualization, FS and MAN; supervision, FS and MAN; project administration, FS; funding acquisition, FS, MAN and IA. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

References

Abad-Segura, E., Gonzalez-Zamar, M. D., Rosa, A. L. D. L., & Morales Cevallos, M. B. (2020). Sustainability of educational technologies: An approach to Augmented Reality research. Sustainability, 12(10), 4091. https://doi.org/10.3390/su12104091

Ahmed, K. G. (2020). Augmented Reality in remote learning: a proposed transformative approach for building construction education. In: Proceedings of the 2020 Sixth International Conference on e-Learning (econf). pp. 115–120.

Alahmari, M. (2023). Exploring the Influential Factors Affecting Staff Willingness to Adopt Augmented Reality. International Journal of Information and Education Technology, 13(7), 1078–1084. https://doi.org/10.18178/ijiet.2023.13.7.1907

Al-araibi, A. A. M., Mahrin, M. N. R. B., & Yusoff, R. C. M. (2019). Technological aspect factors of E-learning readiness in higher education institutions: Delphi technique. Education and Information Technologies, 24, 567–590. https://doi.org/10.1007/s10639-018-9780-9

Ali, M. (2024). Fostering cultural heritage awareness through VR serious gaming: A study on promoting Saudi heritage among the younger generation. Journal of Infrastructure, Policy and Development, 8(3), 3084. https://doi.org/10.24294/jipd.v8i3.3084

Almulla, M. A. (2022). Investigating important elements that affect students' readiness for and practical use of teaching methods in Higher Education. Sustainability, 15(1), 653. https://doi.org/10.3390/su15010653

AlQallaf, N., Elnagar, D. W., Aly, S. G., et al. (2024). Empathy, Education, and Awareness: A VR Hackathon's Approach to Tackling Climate Change. Sustainability, 16(6), 2461. https://doi.org/10.3390/su16062461

Alzahrani, N. M. (2020). Augmented Reality: A systematic review of its benefits and challenges in e-learning contexts. Applied Sciences, 10(16), 5660. https://doi.org/10.3390/app10165660

Augmented RealityKamat, Y., & Nasnodkar, S. (2021). Empirical Investigation of the Impact of 3D Printing on Multiple Dimensions of Student Engagement in STEM Education. Journal of Empirical Social Science Studies, 5(1), 48–73.

Calik, A., Ozkul, D., & Kapucu, S (2024). Smart glasses use experience of nursing graduate students: qualitative study. BMC Nursing, 23(257). https://doi.org/10.1186/s12912-024-01852-w

Carneiro, J., Rossetti, R. J., Silva, D. C., & Oliveira, E. C. (2018). BIM, GIS, IoT, and AR/VR integration for smart maintenance and management of road networks: a review. In: Proceedings of the 2018 IEEE international smart cities conference (ISC2). pp. 1–7.

Chandra, S., & Kumar, K. N. (2018). Exploring Factors Influencing Organizational Adoption of Augmented Reality in E-Commerce: Empirical Analysis Using Technology-Organization-Environment Model. Journal of Electronic Commerce Research, 19(3).

Christopoulos, A., Styliou, M., Ntalas, N., et al. (2024). The Impact of Immersive Virtual Reality on Knowledge Acquisition and Adolescent Perceptions in Cultural Education. Information, 15(5), 261. https://doi.org/10.3390/info15050261

Delello, J. A., McWhoRteR, R. R., & Camp, K. M. (2015). Integrating Augmented Reality in higher education: A multidisciplinary study of student perceptions. Journal of Educational Multimedia and Hypermedia, 24(3), 209–233.

Drljević, N., Botički, I., & Wong, L. H. (2022). Investigating the different facets of student engagement during Augmented Reality use in primary school. British Journal of Educational Technology, 53(5), 1361–1388. https://doi.org/10.1111/bjet.13197

Drljević, N., Botički, I., & Wong, L. H. (2022). Observing student engagement during Augmented Reality learning in early primary school. Journal of Computers in Education, 11(1), 181–213. https://doi.org/10.1007/s40692-022-00253-9

Elfeky, A. I. M., & Elbyaly, M. Y. H. (2021). Developing skills of fashion design by Augmented Reality technology in higher education. Interactive Learning Environments, 29(1), 17–32. https://doi.org/10.1080/10494820.2018.1558259

Eppard, J., Hojeij, Z., Ozdemir-Ayber, P., et al. (2019). Using mobile learning tools in higher education: A UAE Case. International Journal of Interactive Mobile Technologies (IJIM), 13(11), 51. https://doi.org/10.3991/ijim.v13i11.10823

Erdfelder, E., Faul, F., & Buchner, A. (1996). GPOWER: A general power analysis program. Behavior Research Methods, Instruments, & Computers, 28(1), 1–11. https://doi.org/10.3758/bf03203630

Faqih, K. M., & Jaradat, M. I. R. M. (2021). Integrating TTF and UTAUT2 theories to investigate the adoption of Augmented Reality technology in education: Perspective from a developing country. Technology in Society, 67, 101787. https://doi.org/10.1016/j.techsoc.2021.101787

Farhi, F. (2024). Examining the factors fostering metaverse experience browser acceptance under unified theory of acceptance and use of technology (UTAUT). Journal of Infrastructure, Policy and Development, 8(3), 2594. https://doi.org/10.24294/jipd.v8i3.2594

Garzón, J. (2021). An overview of twenty-five years of Augmented Reality in education. Multimodal Technologies and Interaction, 5(7), 37. https://doi.org/10.3390/mti5070037

Gharaibeh, A., Salahuddin, M. A., Hussini, S. J., et al. (2017). Smart cities: A survey on data management, security, and enabling technologies. IEEE Communications Surveys & Tutorials, 19(4), 2456–2501. https://doi.org/10.1109/comst.2017.2736886

Govindan, K., Nasr, A. K., Saeed Heidary, M., et al. (2023). Prioritizing adoption barriers of platforms based on blockchain technology from balanced scorecard perspectives in healthcare industry: A structural approach. International Journal of Production Research, 61(11), 3512–3526. https://doi.org/10.1080/00207543.2021.2013560

Henseler, J. (2017). Partial least squares path modeling. In: Advanced Methods for Modeling Markets. Springer, Cham. pp. 361–381.

Henseler, J., Müller, T., & Schuberth, F. (2018). New guidelines for the use of PLS path modeling in hospitality, travel and tourism research. Applying Partial Least Squares in Tourism and Hospitality Research, 17–33. https://doi.org/10.1108/978-1-78756-699-620181002

Jamali, S., Shiratuddin, M. F., & Wong, K. (2014). An overview of mobile-Augmented Reality in higher education. International Journal on Recent Trends in Engineering & Technology, 11(1), 229–238.

Jarrah, H. Y., & Alkhasawneh, T. (2023). The impact continuous adaptation of augmented reality after Covid-19 in United Arab Emirates. International Journal of Instruction, 16(2), 719–734. https://doi.org/10.29333/iji.2023.16238a

Kshniakin, P. A., Mokeev, A. D., & Chaplygin, S. S. (2021). Infrastructure platform for creating and distributing VR/AR solutions. In: Economic Systems in the New Era: Stable Systems in an Unstable World. Springer International Publishing. pp. 189–196.

Lai, J. S., Crane, P. K., & Cella, D. (2006). Factor analysis techniques for assessing sufficient unidimensionality of cancer related fatigue. Quality of Life Research, 15, 1179–1190. https://doi.org/10.1007/s11136-006-0060-6

Lee, L. K., Wei, X., Chui, K. T., et al. (2024). A Systematic Review of the Design of Serious Games for Innovative Learning: Augmented Reality, Virtual Reality, or Mixed Reality? Electronics, 13(5), 890. https://doi.org/10.3390/electronics13050890

Li, M., & Liu, L. (2023). Students' perceptions of augmented reality integrated into a mobile learning environment. Library Hi

Tech, 41(5), 1498–1523. https://doi.org/10.1108/lht-10-2021-0345

Liarokapis, F., & Anderson, E. F. (2010). Using Augmented Reality as a medium to assist teaching in higher education. In: Proceedings of the Eurographics 2010—Education Papers.

López-Belmonte, J., Moreno-Guerrero, A. J., López-Núñez, J. A., & Hinojo-Lucena, F. J. (2023). Augmented Reality in education. A scientific mapping in Web of Science. Interactive learning environments, 31(4), 1860–1874. https://doi.org/10.1080/10494820.2020.1859546

Lu, S. J., & Liu, Y. C. (2015). Integrating augmented reality technology to enhance children's learning in marine education. Environmental Education Research, 21(4), 525–541. https://doi.org/10.1080/13504622.2014.911247

Martín-Gutiérrez, J., Fabiani, P., Benesova, W., et al. (2015). Augmented Reality to promote collaborative and autonomous learning in higher education. Computers in Human Behavior, 51, 752–761. https://doi.org/10.1016/j.chb.2014.11.093

Matsika, C., & Zhou, M. (2021). Factors affecting the adoption and use of AVR technology in higher and tertiary education. Technology in Society, 67, 101694. https://doi.org/10.1016/j.techsoc.2021.101694

Moro, C., Štromberga, Z., Raikos, A., & Stirling, A. (2017). The effectiveness of virtual and Augmented Reality in health sciences and medical anatomy. Anatomical Sciences Education, 10(6), 549–559. https://doi.org/10.1002/ase.1696

Munnerley, D., Bacon, M., Fitzgerald, R., et al. (2014). Augmented Reality: Application in higher education. Office for Learning and Teaching, 10(1), 3121–7445.

Murrell, S., Wang, F., Aldrich, E., & Xu, X. (2020). MeteorologyAR: A Mobile AR App to Increase Student Engagement and Promote Active Learning in a Large Lecture Class. In: Proceedings of the 2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW). pp. 848–849.

Nesenbergs, K., Abolins, V., Ormanis, J., & Mednis, A. (2020). Use of augmented and virtual reality in remote higher education: A systematic umbrella review. Education Sciences, 11(1), 8. https://doi.org/10.3390/educsci11010008

Papaevangelou, O., Syndoukas, D., Kalogiannidis, S., & Chatzitheodoridis, S. (2024). Efficacy of embedding IT in human resources (HR) practices in education management. Journal of Infrastructure, Policy and Development, 8(1), 2371. https://doi.org/10.24294/jipd.v8i1.2371

Petrovych, O., Zavalniuk, I., Bohatko, V., et al. (2023). Motivational Readiness of Future Teachers-Philologists to Use the Gamification with Elements of Augmented Reality in Education. International Journal of Emerging Technologies in Learning, 18(3), 4–21. https://doi.org/10.3991/ijet.v18i03.36017

Radosavljevic, S., Radosavljevic, V., & Grgurovic, B. (2020). The potential of implementing Augmented Reality into vocational higher education through mobile learning. Interactive Learning Environments, 28(4), 404–418. https://doi.org/10.1080/10494820.2018.1528286

Rodríguez-Abad, C., Martínez-Santos, A. E., Fernandez-de-la-Iglesia, J. D. C., & Rodríguez-Gonz´alez, R. (2023). Online (versus face-to-face) augmented reality experience on nursing students' leg ulcer competency: Two quasi-experimental studies. Nurse Education in Practice, 71, 103715. https://doi.org/10.1016/j.nepr.2023.103715

Sáez-López, J. M., Cózar-Gutiérrez, R., González-Calero, J. A., & Gómez Carrasco, C. J. (2020). Augmented Reality in higher education: An evaluation program in initial teacher training. Education Sciences, 10(2), 26. https://doi.org/10.3390/educsci10020026

Saidin, N. F., Halim, N. D. A., & Yahaya, N. (2015). A review of research on Augmented Reality in education: Advantages and applications. International education studies, 8(13), 1–8. https://doi.org/10.5539/ies.v8n13p1

Salem, O., Samuel, I. J., & He, S. (2020). Bim And Vr/Ar Technologies: From Project Development to Lifecycle Asset Management. In: Proceedings of the International Structural Engineering and Construction; Angamaly, India. pp. 14–15.

Snyder, M. M., Kramer, S., Lippe, D., & Sankar, S. (2023). Design and Implementation of 360-Degree Video Vignettes in Immersive Virtual Reality: A Quality Management in Higher Education Case. The Qualitative Report, 28(7), 2113–2155. https://doi.org/10.46743/2160-3715/2023.6140

Soltis, N. A., McNeal, K. S., Atkins, R. M., & Maudlin, L. C. (2020). A novel approach to measuring student engagement while using an Augmented Reality sandbox. Journal of Geography in Higher Education, 44(4), 512–531. https://doi.org/10.1080/03098265.2020.1771547

Sosnovska, O., & Zhytar, M. (2018). Financial architecture as the base of the financial safety of the enterprise. Baltic Journal of Economic Studies, 4(4), 334–340. https://doi.org/10.30525/2256-0742/2018-4-4-334-340

Srivastava, A. (2016). Enriching student learning experience using Augmented Reality and smart learning objects. In: Proceedings of the 18th ACM International Conference on Multimodal Interaction. pp. 572–576.

Stalheim, O. R., & Somby, H. M. (2024). An embodied perspective on an augmented reality game in school: pupil's bodily experience toward learning. Smart Learning Environments 11(2), 1–21. https://doi.org/10.1186/s40561-024-00308-7

Suresh, K. P., & Chandrashekara, S. (2012). Sample size estimation and power analysis for clinical research studies. Journal of Human Reproductive Sciences, 5(1), 7. https://doi.org/10.4103/0974-1208.97779

Taha, S., Abulibdeh, E., Qunais, J., et al. (2023). Exploring the Utilization of Augmented Reality in Higher Education Perceptions of Media and Communication Students. Emerging Science Journal, 7. https://doi.org/10.28991/ESJ-2023-SIED2-016

Udeozor, C., Chan, P., Abegão, F. R., & Glassey, J. (2023). Game-based assessment framework for virtual reality, augmented reality and digital game-based learning. International Journal of Educational Technology in Higher Education, 20(1), 1–22. https://doi.org/10.1186/s41239-023-00405-6

Visvizi, A., Lytras, M. D., & Sarirete, A. (2019). Management and administration of higher education institutions at times of change. Emerald Publishing Limited.

Wong, J. Y., Azam, A. B., Cao, Q., et al. (2024). Evaluations of Virtual and Augmented Reality Technology-Enhanced Learning for Higher Education. Electronics, 13(8), 1549. https://doi.org/10.3390/electronics13081549

Xanthidis, D., Manolas, C., Paul, S., & Xanthidou, O. K. (2020). Virtual and Augmented Reality: Enhancing the learning experience in higher education in the UAE Current standing & research directions. In: Proceedings of the 2020 Seventh International Conference on Information Technology Trends (ITT). pp. 206–211.

Yuen, S. C. Y., Yaoyuneyong, G., & Johnson, E. (2011). Augmented Reality: An overview and five directions for AR in education. Journal of Educational Technology Development and Exchange (JETDE), 4(1), 11. https://doi.org/10.18785/jetde.0401.10

Appendix

Questionnaire items:

Data management:

1) Efficient data management systems are essential for the effective integration of augmented reality (AR) in higher education.
2) It is imperative to implement proactive strategies for effective management of AR data in higher education institutions in the United Arab Emirates (UAE).
3) Efficient AR data management systems improve the quality of education by offering students enhanced learning possibilities.
4) To successfully incorporate augmented reality (AR) into higher education, it is crucial to effectively manage data risks in order to sustain technical innovation and preserve a competitive advantage.
5) Adopting sophisticated data management techniques is crucial in order to stay up to date with the rapid advancements in augmented reality (AR) technology worldwide.
6) The UAE’s focus on technology advancement underscores the significance of efficient AR data management in revolutionizing education.

Items measuring technological limitations:

1) The existing technology infrastructure is insufficient for effectively handling and distributing Augmented Reality (AR) data.
2) The integration of Building Information Modeling (BIM) with augmented reality (AR) and virtual reality (VR) encounters substantial technological obstacles.
3) An adequate technical infrastructure is crucial for successfully creating and implementing augmented reality solutions.
4) The management of augmented reality (AR) data is often limited by the constraints of the current technological infrastructure.
5) The intricacy of infrastructure functions has a substantial influence on the efficient implementation of AR technologies.
6) To overcome current constraints, the maintenance and administration of intelligent road networks need improvements in Building Information Modeling (BIM), Geographic Information Systems (GIS), Internet of Things (IoT), and augmented reality/virtual reality (AR/VR) technologies.

Faculty readiness:

1) The faculty members are ready to incorporate modern technology into their methods of instruction.
2) Faculty members have access to enough training to keep current with new instructional technology.
3) Members of the faculty are sure that they can employ digital resources and platforms in their courses with effectiveness.
4) The teachers are flexible and eager to welcome technological advancements in order to improve the educational process.
5) Enough support mechanisms are in place to help teachers use new instructional technology.

Students’ engagement:

1) Students actively participate in the use of augmented reality (AR) technologies, so greatly increasing their educational experience.
2) The use of augmented reality (AR) technology in educational settings facilitates increased levels of student engagement and collaboration.
3) Engaging with augmented reality (AR) technologies enhances pupils’ ability to effectively handle and comprehend information supplied by AR.
4) Students exhibit heightened curiosity and drive while using augmented reality technologies in their academic

pursuits.

5) Active engagement with augmented reality (AR) information has a beneficial effect on students' capacity to remember and apply knowledge.
6) Integrating AR technologies into the curriculum enhances the interactivity and engagement of the learning environment for students.

Financial constraint:

1) Insufficient financial resources provide a major obstacle to the adoption and implementation of augmented reality (AR) in higher education institutions.
2) The significant expenses linked to augmented reality (AR) technology provide considerable obstacles to incorporating it into educational programs.
3) Financial limitations influence the decision-making process about the use of augmented reality (AR) technologies in higher education.
4) Insufficient financing hinders colleges from properly harnessing the promise of augmented reality (AR) technology in their courses.
5) Institutions have practical challenges in using augmented reality (AR) technology as a result of financial constraints.
6) Efficient allocation and management of financial resources are vital for the successful adoption of augmented reality (AR) in higher education.