technologies

MDPI

Article

Barriers to the Adoption of Augmented Reality Technologies for Education and Training in the Built Environment: A Developing Country Context

Opeoluwa Akinradewo [1,2,*], Mohamed Hafez [2], John Aliu [3], Ayodeji Oke [4], Clinton Aigbavboa [4] and Samuel Adekunle [4]

1 Department of Quantity Surveying and Construction Management, Faculty of Natural and Agricultural Sciences, University of the Free State, Bloemfontein 9301, South Africa
2 Civil Engineering Department, Faculty of Engineering and Quantity Surveying, INTI-International University, Nilai 71800, Malaysia; mohdahmed.hafez@newinti.edu.my
3 Engineering Education Transformations Institute, College of Engineering, University of Georgia, Athens, GA 30602, USA; ajseries77@gmail.com
4 Cidb Centre of Excellence, Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg 2092, South Africa; emayok@gmail.com (A.O.)
* Correspondence: opeakinradewo@gmail.com

Abstract: The construction industry has been tasked to adapt to technological advancements that other industries have implemented to grow and remain relevant. One of these technological advancements is augmented reality technologies. ART combines real and virtual worlds without completely immersing the individual in a virtual simulation. The use of ART can significantly improve education and training, especially in the construction industry, by analysing real-world environments while training in a controlled setting. This study, therefore, sets out to identify the factors that hinder the use of ART in the built environment. To achieve this, a quantitative research approach was adopted, and questionnaires were distributed to professionals in the built environment using South Africa as the research location. Retrieved data were analysed using both descriptive and inferential statistics. Findings revealed that investment cost is the major hindrance stakeholders face in implementing ART for education and training in the built environment. The exploratory factor analysis result clustered the identified barriers as internal organisation-related, culture-related, knowledge-related, and educator-related barriers. The study concluded that stakeholders in the built environment still have major responsibilities to ensure there is proper awareness of the benefits of adopting ART for education and training.

Keywords: augmented reality technologies; built environment; developing countries; education; training

Academic Editor: Ahmad Lotfi

Received: 3 December 2024
Revised: 16 January 2025
Accepted: 21 January 2025
Published: 3 February 2025

Citation: Akinradewo, O.; Hafez, M.; Aliu, J.; Oke, A.; Aigbavboa, C.; Adekunle, S. Barriers to the Adoption of Augmented Reality Technologies for Education and Training in the Built Environment: A Developing Country Context. *Technologies* **2025**, *13*, 62. https://doi.org/10.3390/technologies13020062

1. Introduction

For the construction sector to develop and stay relevant, it must adopt digitalisation and technological innovations in other industries and sectors, such as the manufacturing industry [1]. Digitalisation has the potential to improve nearly every element of the construction business, including project management, budgetary compliance, and health and safety [2]. A semi-immersive technology called augmented reality (AR) enables users to view computer-generated content overlaid in the real world in real-time [3]. Without totally submerging the user in a virtual simulation, AR combines the real and virtual worlds [4]. Aghimien [5] claimed that technology is developing at a stunning rate as it is incorporated into our daily lives and is also changing how we live. According to Li [6], AR can considerably improve education and safety training by studying real-world situations while training in a controlled environment, notably in the construction industry.

Given the benefits of using AR in the construction sector, educating clients on how to interact with this technology is crucial. AR technologies offer immersive and interactive learning experiences that enhance spatial problem-solving, foster a greater understanding of complex structures, and improve decision-making processes. Deshpande [7] highlighted that AR's ability to present spatially contextualised information can significantly aid in comprehending object assembly, which is directly relevant to construction projects. Moreover, Radu [8] emphasised the role of AR in reducing cognitive load by providing real-time visualisations and contextual guidance, making it a valuable tool for both professional training and client education. Diegmann [9] conducted a literature review that identified key benefits of AR in educational environments, such as enhanced understanding of abstract concepts and improved learner performance. These findings are particularly relevant in the construction sector, where AR can be employed to educate clients about project designs, material choices, and construction phases through interactive 3D models. Furthermore, Martinez [10] argued that AR supports practical training and bridges the gap between theoretical knowledge and real-world applications, making it a powerful tool for client interaction and education. Hence, learners must actively interact with the technology in a learning environment for learning to occur [11,12].

According to Ohler [13], students today favour using visual media over reading, listening, and recalling techniques utilised by prior generations. According to Radu [8], the accessibility of smartphones has made AR a teaching tool that is extremely accessible to students at all levels. Additionally, students can now access extra learning possibilities like interactive simulations and games, even those in elementary school. According to Mupfunya [14], technology has demonstrated benefits for education since it fosters critical thinking and accelerates the learning process. While augmented reality technologies (ART) are widely accessible in developed nations, they are less common in typical developing nations like South Africa. However, as smartphones become more extensively used, technology will advance to the point where ART is broadly accessible on more reasonably priced devices. According to Rodrriguez-Pardo [15], handheld devices are the ideal choice for a basic ART experience because they are affordable and have a lot of sensors for locating ART objects.

Before beginning site activities, construction employees should get education and training to ensure they know all the specifics of each task, including any potential risks or dangers [16]. Construction is known for its tendency to have a higher fatality rate and to have staff members work fewer hours. By spotting possible risks before jobs are completed, accidents in the construction industry can be averted with ART education and training [17]. In addition, it should be remembered that the building sector is entering a new era of technology, and quick action is required to move the world forward. These technologies must be incorporated into every scope within the construction ecosystem because the world is evolving around the fourth industrial revolution (4IR). As a result, this study aims to identify the factors that hinder the use of ART in the built environment. This is with the intent to sensitise the stakeholders involved in the built environment on the different factors to focus on to promote the adoption of ART.

2. Barriers to Augmented Reality Technologies Adoption

Although augmented reality technology may have only recently gained widespread popularity, by 2026, the market is anticipated to be worth more than $80 billion [18]. In addition to impacting various industries, augmented reality technology (ART) has introduced innovative possibilities in academia. It provides teachers and students with enhanced teaching and learning experiences by integrating interactive and visual elements into classroom settings [19]. Studies have shown that ART facilitates learning by improving students' understanding, retaining, and recalling information. Additionally, it assists teachers in explaining complex subjects and offering visual representations that enhance comprehension [8,9]. Although AR&VR may be useful for various beneficial causes, there are numerous obstacles to implementing it in education and training. Additionally, no educational institution wants to fall behind in the age of digital revolution, especially when it comes to utilising tools that facilitate procedures. As a result, they accept new developments and implement them into their daily operations [14].

Adopting augmented reality technologies (ART) in the built environment was hindered by significant barriers, beginning with the investment cost required for implementation. High initial costs deterred organisations and educational institutions, especially when the return on investment (ROI) was unclear. Studies by Oke [20] and Afolabi [21] emphasised the need for comprehensive cost-benefit analyses to justify ART adoption. Institutions often considered phased implementation to spread costs and demonstrate tangible benefits over time. Without clear financial justification, decision-makers remained hesitant to invest. Another critical barrier was the lack of experience among stakeholders in effectively utilising ART. While leaders in construction firms expressed enthusiasm for innovation, they often lacked the technical expertise to implement ART effectively [22,23]. This knowledge gap led to poor planning and resistance to adoption, as organisations were unprepared to address the challenges that arose during the transition. Training programs tailored to build familiarity with ART were essential to bridging this gap and ensuring smooth integration.

Effective adoption of ART requires robust systems to manage data related to requirements, design documentation, testing, and evaluation. However, as Gausdal [24] and Adekunle [25] noted, many organisations in the built environment lacked the infrastructure and policies to ensure proper data management. This deficiency hindered transparency, accountability, and stakeholder collaboration, creating bottlenecks in the adoption process. A clear and effective strategy was another obstacle to ART adoption. Transitioning from traditional methods to digital tools like ART demanded meticulous planning and phased implementation to minimise disruptions [26,27]. Institutions often struggle to engage all stakeholders effectively, leading to resistance and misalignment. Developing well-defined objectives and actively involving employees in the transition process reduced uncertainty and fostered a sense of ownership.

Additionally, concerns about health and safety (H&S) presented challenges for the construction industry, which had long struggled with inadequate H&S implementation. The integration of ART in education and training could have addressed these gaps by simulating real-world scenarios and improving safety awareness. However, as Malomane [28] highlighted, the industry's reluctance to prioritise H&S limited ART's potential to revolutionise safety standards. Finally, reluctance to change remained pervasive, particularly among educators and professionals accustomed to traditional methods. Fernandez [29] and Rejeb [30] argued that adopting ART required technical adjustments and significant curricular overhauls. The process involved redesigning educational programs to leverage ART's full potential, which many institutions were unwilling to undertake due to perceived risks and resistance to innovation.

To operationalise the identified barriers, as shown in Table 1, it was essential to state specifically the barriers that are particularly relevant to education and training in the built environment within a developing country context. Several barriers, such as investment cost, lack of resources, and poor information management, were more pronounced in developing countries due to limited financial capacity, infrastructural deficiencies, and inadequate policies for managing and safeguarding data. These constraints significantly affect the ability of institutions in developing countries to integrate ART into their education systems. Barriers such as legacy infrastructure and reluctance to change were particularly critical in the context of the built environment. The reliance on outdated systems and methods often impedes the adoption of new technologies like ART, especially in educational institutions that lack the agility to adapt quickly. This was further compounded by resistance from educators and administrators accustomed to traditional pedagogical approaches. Integrating ART into curricula requires significant cultural and institutional shifts in such environments.

Table 1. Identified barriers to the adoption of ART.

S/N	Barriers	Sources
1	Investment cost	[20,21,31]
2	Lack of experience	[22,23]
3	Poor information management	[24,25,32]
4	Lack of effective strategy	[26,27,33]
5	Health and Safety	[28,34]
6	Reluctance to change	[29,30]
7	Legacy Infrastructure	[35,36]
8	Organisational structure	[37,38]
9	Organisational leadership	[39,40]
10	Lack of resources	[41,42]
11	Support systems	[7,43]
12	Gamification	[44,45]
13	Job insecurity	[46,47]
14	Toxic work environment	[48,49]
15	Implausibility of the organisation	[50,51]
16	Lack of organisational awareness	[52,53]
17	Organisational mission and vision	[10,54]
18	Limited knowledge of AR's benefits	[9,19]

In the specific domain of education and training in the built environment, barriers such as health and safety and limited knowledge of ART's benefits were highlighted. Developing countries often face challenges in enforcing health and safety standards within the construction industry, directly impacting the use of technologies like ART that could improve safety training. Additionally, a lack of awareness about the educational benefits of ART among policymakers and educators limits its adoption as a teaching tool. The developing country context further exacerbates issues like job insecurity and organisational awareness. Concerns about job displacement due to digitalisation are more pronounced in regions with high unemployment rates, making workers wary of technologies perceived as threatening their livelihood. Similarly, low levels of organisational awareness in developing countries hinder the strategic alignment required for the successful adoption of ART.

3. Research Methodology

The barriers to the adoption of ART for education and training in the built environment were investigated using a quantitative research method, while preliminary information was gathered using a literature review. A systematic literature review (SLR) method was conducted to ensure a comprehensive and rigorous analysis of existing research on augmented reality technologies (ART) in teaching and its adoption within the built environment. Articles were systematically identified and selected from reputable databases, including SCOPUS and Web of Science, using predefined search terms such as “augmented reality”, “teaching and training”, “built environment”, and “developing countries”. The search focused on peer-reviewed journal articles, conference proceedings, and reviews published between 2010 and 2024 to capture the evolution of ART adoption over time. Inclusion criteria ensured that the selected articles were directly relevant to the research objectives, while exclusion criteria eliminated studies that did not expressly focus on ART or its application in education and training within the built environment sector.

South Africa’s Gauteng province was chosen as the target location for this investigation due to its significant contribution to the built environment sector. Gauteng is the economic hub of South Africa, hosting a high concentration of construction activities, including commercial, residential, and infrastructural developments, which makes it an ideal region for studying barriers to augmented reality adoption in the built environment. Furthermore, the province has a higher building rate and concentration of built environment professionals compared to other regions, offering a diverse pool of participants with relevant expertise.

The study targeted built environment professionals, including architects, civil engineers, mechanical engineers, electrical engineers, project managers, construction managers, and quantity surveyors, as they represent key stakeholders in the adoption of augmented reality technologies. The study employed a convenience sampling approach to ensure the practical feasibility of reaching participants actively engaged in construction projects within Gauteng [55]. The population size and its constitution were not explicitly determined due to constraints in accessing comprehensive records of the professionals in Gauteng province. The constraint is influenced by compliance with the Protection of Personal Information Act (POPIA) in South Africa, which governs the processing and sharing of personal information to protect individuals’ privacy. This regulatory framework restricts access to databases containing personal and professional details without explicit consent, posing a challenge to obtaining a fully comprehensive sampling frame. However, a generic search for these professionals on LinkedIn and restricted to Gauteng province indicated a total population of 5645. Using a 99% confidence level at an 8% margin of error, a sample size of 250 was achieved and adopted for the study. A total of 250 questionnaires were distributed electronically using the accounts of the professionals on LinkedIn, with 235 valid responses received, representing a 90% response rate.

The questionnaire was designed into two sections on Google Forms, where section A retrieved demographic information of the respondents while section B focused on the identified barriers from reviewed literature using close-ended questions. The questionnaire was carefully designed to not solicit personal information that could reveal the identity of the respondents in line with the obtained ethics clearance for the data collection process. The results of the five-point Likert scale questions used in this research were revealed using the mean item score (MIS). The mean is the most often used measure of central tendency, according to Eekhout [56]. The MIS index represents the overall participants’ actual scores (as determined by each respondent using a five-point agreement Likert scale) expressed as a percentage of all the greater probable results on the Likert scale that each respondent may add to that criterion. Additionally, the retrieved data were also subjected to exploratory factor analysis (EFA). Using EFA, one can examine the theoretical underpinnings of the phenomena and condense data to a smaller set of summary variables [57]. Along with the EFA used, it was important to verify the accuracy of the data acquired. After establishing the content validity and doing preliminary data analysis, tests for empirical and theoretical reliability were carried out for this study [58]. The reliability test conducted revealed a Cronbach alpha value of 0.926, indicating that the data collection instrument meets the required threshold of 0.7 and can be relied upon to make reasonable conclusions from the findings of the study.

4. Findings and Discussion

According to the findings of the descriptive analysis, 41.9% of respondents reported an honours degree as their highest qualification. Additionally, 7% indicated matric as their highest qualification, 7% held a post-matric certificate or diploma, 14% held a bachelor's degree, 18.6% held a master's degree, and 11.6% of respondents reported holding a doctorate. Architects make up 9% of the professional group, civil engineers 9%, construction managers 12%, mechanical and electrical engineers 2%, project managers 14%, and quantity surveyors 54%, which is the majority. The findings also revealed that 7% of the respondents have less than 12 months of working experience, 21% have between 1 and 5 years of experience, 18% of respondents have between 6 and 10 years of experience, 19% have between 11 and 15 years of experience, while 35% have above 15 years of experience in the industry. A total of 2% of the respondents work for developers, 16% work for government departments, 28% work for consultancy firms, 12% work for contracting organisations, and the majority (42%) work in academia. Finally, the demographic results show that 56% of the respondents work for large organisations with more than 250 employees, 16% for medium-sized organisations with 51 to 250 employees, 14% for small organisations, and 14% work for micro organisations.

Table 2 shows participants' responses to the barriers to the adoption of ART for education and training. The most predominant barrier is "Investment cost" with a mean score (MS) of 3.30 and a standard deviation (SD) of 0.741. The other predominant barriers include "Lack of experience" (MS = 3.28; SD = 0.666), "Reluctance to change" (MS = 3.23; SD = 0.684), "Poor information management" (MS = 3.09; SD = 0.684), and "Lack of resources" (MS = 3.02; SD = 0.771). The least ranked barrier as perceived by the respondents is "Limited knowledge of ART benefits" (MS = 2.28; SD = 1.054). Other lowly ranked barriers as perceived by the respondents include "Implausibility of the organisation" (MS = 2.67; SD = 0.969), "Health and safety" (MS = 2.40; SD = 1.137), "Job insecurity" (MS = 2.56; SD = 0.881) and "Organisational mission and vision" (MS = 2.60; SD = 0.728).

Before applying exploratory factor analysis (EFA) to the data, the necessary assumptions were tested to ensure the appropriateness of the analysis. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy, which evaluates whether the sample size is sufficient to yield reliable factor analysis results, was computed. As shown in Table 3, the KMO value was 0.718, which surpasses the minimum threshold of 0.6 and falls within the "good" range, indicating that the data were suitable for factor analysis [59]. Additionally, Bartlett's test of sphericity was conducted to assess whether the variables in the dataset were sufficiently correlated to justify factor analysis. The test was statistically significant ($p < 0.05$), confirming that the data matrix was not an identity matrix and was, therefore, factorable. These results satisfied the assumptions for EFA, validating the use of this technique for identifying underlying factor structures in the study.

Table 2. Barriers to the adoption of ART.

Barriers	Mean Score (MS)	Std. Deviation (SD)	Rank
Investment cost	3.30	0.741	1
Lack of experience	3.28	0.666	2
Reluctance to change	3.23	0.684	3
Poor information management	3.09	0.648	4
Lack of resources	3.02	0.771	5
Legacy infrastructures	2.86	0.861	6
Lack of Organisational awareness	2.81	0.699	7
Organisational leadership	2.79	0.861	8
Gamification	2.79	0.888	9
Lack of effective strategy	2.77	0.718	10
Toxic work environment	2.72	0.908	11
Support systems	2.67	0.715	12
Organisational structure	2.63	0.655	13
Organisational mission and vision	2.60	0.728	14
Job insecurity	2.56	0.881	15
Health and safety	2.40	1.137	16
Implausibility of the organisation	2.33	0.969	17
Limited knowledge of ART benefits	2.28	1.054	18

Table 3. KMO and Bartlett's test and validity test.

KMO and Bartlett's Test		
Kaiser–Meyer–Olkin measure of sampling adequacy		0.718
Bartlett's test of sphericity	Approx. Chi-square	505.240
	Df	153
	Sig	0.000
Reliability Test		
Cronbach's Alpha	0.868	

The total variance explained in Table 4 demonstrates the barriers to the adoption of ART and respective eigenvalues. The Kaiser's criterion of retaining factors with eigenvalues exceeding 1.0 was employed. However, only four factors were retained in Table 4. The variance of the extracted factor 1 is 41.068%, factor 2 (12.542%), factor 3 (9.193%) and finally factor 4 (6.587%). The final statistics of the extracted factors and PCA account for approximately 70% of the overall cumulative variance.

Table 4. Barriers total variance explained.

Total Variance Explained							
Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	7.392	41.068	41.068	7.392	41.068	41.068	4.792
2	2.258	12.542	53.610	2.258	12.542	53.610	5.138
3	1.655	9.193	62.802	1.655	9.193	62.802	2.554
4	1.186	6.587	69.389	1.186	6.587	69.389	4.146
5	0.955	5.304	74.693				
6	0.820	4.554	79.246				
7	0.792	4.399	83.645				
8	0.546	3.035	86.680				
9	0.537	2.985	89.665				
10	0.462	2.568	92.234				
11	0.349	1.937	94.171				
12	0.280	1.557	95.727				
13	0.237	1.318	97.045				
14	0.167	0.928	97.972				
15	0.132	0.736	98.708				
16	0.096	0.533	99.241				
17	0.088	0.491	99.733				
18	0.048	0.267	100.000				

Extraction method: Principal factor analysis. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

Eighteen variables identified from the literature were factored into four clusters, which are then interpreted based on the observed intrinsic relationship among the variables in the cluster, as shown in Table 5. which shows the pattern matrix.

i. A total of four variables were loaded onto cluster 1, as shown in Table 5. These variables are 'Organisational structure' (87.4%), 'Organisational leadership' (83.0%), 'Lack of resources' (59.6%) and 'Gamification' (41.1%). All these can be observed to relate to the structure. The first variable was considered when naming the cluster because it has the highest impact on the cluster [60]. Similar consideration was employed in naming subsequent clusters for this research. Therefore, this factor cluster can be termed '**Internal organisation-related barriers**' with a variance of 41.068%, making it a major barrier to the adoption of ART for education and training in the built environment. The reliability report for this cluster showed a Cronbach's alpha value of 0.874.
ii. In cluster 2, there are seven variables loaded onto it. These variables are 'Toxic work environment' (90.4%), 'Implausibility of the organisation' (78.7%), 'Lack of organisational awareness' (77.2%), 'Organisational mission and vision' (73.3%) 'Job insecurity' (71.9%), 'Health and Safety' (45.4%) and 'Support system' (40.4%). The common factor to the variables in this cluster is related to the organisational culture of the establishment. The cluster is therefore labelled '**Culture-related barriers**'

with a total variance of 12.542%. This cluster is ranked as a barrier to the adoption of ART for education and training in the built environment behind the variables in cluster 1. The reliability report for this cluster showed Cronbach's alpha value of 0.901.

iii. Cluster 3 has three variables loaded onto it, and these variables are 'Limited knowledge of ART benefits' (78.0%), 'Investment cost' (69.3%), and 'Lack of experience' (59.1%). These variables relate largely to having adequate knowledge of the recent global advancements and are therefore labelled '**Knowledge-related barriers**'. This cluster gathered 9.193% of the total variance to be ranked the third classification of barriers to the adoption of ART for education and training in the built environment. The reliability report for this cluster showed Cronbach's alpha value of 0.935.

iv. The fourth cluster consists of four variables, which are 'Legacy infrastructure' (−77.4%), 'Poor information management' (−72.2%), 'Lack of resources' (−64.6%) and 'Reluctance to change' (−62.3%). As observed in this scenario, the item is negatively correlated with the factor. When an item generates a negative factor loading, the raw score of the item is deducted rather than added to the computations [61]. This implies that higher levels of these variables are associated with weaker alignment to the factor. In this context, the negative loadings do not necessarily mean that these components lack any relationship with the factor but rather suggest that their influence is inversely related. These four factors are related to old-fashioned methods of operating as an organisation, which gives the cluster the label '**Traditional-Problem-Related Barriers**'. This interpretation aligns with their conceptual relevance to traditional problems that hinder innovation and the adoption of modern technologies. This cluster had a total variance of 6.587%, and the reliability report for this cluster showed Cronbach's alpha value of 0.882.

Mirković [37] discussed the barriers and hypothesised that they might develop as a result of how an organisation feels about using digital technology. They referred to these impediments as internal barriers and contend that it is more difficult to recognise and address how staff members and other stakeholders in establishments perceive and feel about digital technology. According to the author, one of the internal obstacles was connected to organisational structure and leadership. Additionally, the gamification of technology raises internal barriers that may eventually cause workers to avoid using digital technologies, such as unhealthy rivalry among employees and a lack of confidence in one's own computer skills. Another internal organisational barrier to the adoption of ART is the lack of incentives and motives, which results in the worker's lack of recognition or rewards for their efforts to use digital technologies, as highlighted by Semenets-Orlova [40]. The attitude toward digital technologies may suffer when incentives are not provided for the construction educator's and staff's extra effort to include digital technologies into their curriculum and activities.

The study's findings indicate that cultural barriers are the second hurdle. These hurdles are characterised by the absence of a common vision, a lack of organisational understanding, and challenges in dealing with employees' or other relevant staff members' divergent viewpoints on using digital technology for education and training [48,50]. The results show that job insecurity and support structures are additional barriers that can be attributed to the perspective of organisational connected with regard to the other barriers defined in the cluster. According to Pereira [52], employees will not be motivated to use digital devices if the organisational culture does not support training them in digitalisation. Stakeholders are not given the required training to use sophisticated technology like augmented reality.

Table 5. Barrier's pattern matrix.

Pattern Matrix					
	Factor				
	1	**2**	**3**	**4**	
Organisational structure	0.874				**Internal Organisations-Related Barriers**
Organisational leadership	0.830				
Readily available resources	0.596				
Gamification of the technology	0.411				
Unstable work environment		0.904			**Culture-Related Barriers**
Not sustainable		0.787			
Organisational awareness		0.772			
Organisational mission and vision		0.733			
Insecure workforce		0.719			
Negatively affect health and safety		0.454			
Support structure		0.404			
Lack of experience			0.780		**Knowledge-Related Barriers**
Do not see the benefits of ART			0.693		
Investment cost			0.591		
Not ready to change				−0.774	**Traditional problem-related barriers**
Lack of information				−0.722	
Lack of resources				−0.646	
Reluctance to change				−0.623	

Lack of knowledge is yet another barrier to the adoption of ART. All employees need to have their fears, anxieties, and misgivings allayed by the organisation's leadership owning and communicating the advantages and reasons for adopting the technology. Before it is operationalised, digital transformation has the potential to be disruptive, altering established roles, processes, and expectations. Educators are expected to worry that implementing ART in construction operations will be expensive, and businesses frequently hesitate to entrust corporate teaching activities solely to a computer [23]. For these reasons, it is essential to introduce change gradually, involve all relevant parties, clearly explain the advantages and justifications for the initiative, and offer a safe space for queries and grievances. Given the ambiguity surrounding what digital transformation actually entails and how it will benefit learners, starting the process and persuading others to adopt it will be challenging [19]. The establishment must have the necessary information and understanding if it is launching new digital channels and revenue sources through technology.

The final cluster demonstrated how the connection to established practices influences whether ART is used in education and training. The educators and trainers are concerned with the new infrastructure to be used. This is because they understand the old infrastructure well, and changing their methodological approach to accommodating digitalisation will require preparedness [24]. Besides reluctance to change, Schuir [35] talked about the lack of resources as a militating factor in adopting ART. The authors emphasised how important it is for all construction students to regularly have access to digital tools so they can learn the specifics of each one. Understanding the distinction between blended learning and conventional learning methods is crucial. These significant variables show rather sensible standards on which instructors decide whether or not to use digital technology in the classroom. According to the author's understanding, these elements, however, can become barriers when teachers decide not to use a digital tool because of one or more of these elements.

5. Conclusions and Recommendations

This study explored the barriers to adopting augmented reality technologies (ART) for education and training within the built environment sector. The findings reveal that people, rather than technology, constitute the primary barriers to the digital revolution in this field. Resistance to change, insufficient knowledge, and entrenched traditional practices present significant obstacles to the successful adoption of ART. This underscores the importance of focusing on the human component in addition to the strategic implementation of ART. To address these challenges, stakeholders in the built environment education sector must prioritise creating a supportive culture that encourages technological adoption. Institutions and organisations should develop comprehensive strategies that address internal organisational barriers, cultural resistance, and traditional problem-associated obstacles. Successful ART implementation requires a phased approach, starting with early adopters who can champion the transformation and gradually expanding to include other groups. Resistance to change is often rooted in a perception that existing methods are sufficient. Therefore, leadership must effectively communicate the benefits of ART and align the transformation with broader organisational and educational goals. From a curricular and educational perspective, policymakers must integrate ART into the curriculum of built environment programs in higher education institutions. This will involve revising course content to incorporate ART-based tools and applications and providing hands-on training opportunities for students. Institutions should also prioritise acquiring the necessary infrastructure to support ART integration, such as AR-enabled devices, software, and training facilities. Collaborative efforts between academic institutions, industry stakeholders, and technology providers are essential to ensure the sustainability of such initiatives.

Several strategic measures can be implemented to overcome the constraints associated with adopting augmented reality technologies (ART). One critical approach is to provide ongoing training and development programs for educators, students, and professionals. These initiatives would enhance their technical skills and deepen their familiarity with ART tools, ensuring they are well-equipped to integrate these technologies effectively. Additionally, policy support is essential in fostering ART adoption. Government incentives and funding schemes can play a pivotal role in assisting educational institutions to acquire the necessary infrastructure, such as AR-enabled devices and software, to facilitate the integration of ART into educational practices. Collaboration between educational institutions and technology providers through public-private partnerships is another key measure. Such partnerships can help bridge resource gaps and enable the sharing of expertise, thereby accelerating the adoption process. Awareness campaigns are also vital in addressing misconceptions and highlighting the practical benefits of ART. Workshops and seminars can be organised to showcase its potential to transform education and training in the built environment, thereby encouraging broader acceptance among stakeholders. Lastly, a gradual and phased implementation of ART is recommended. This approach allows institutions to introduce the technology incrementally, providing time for users to adapt and minimising resistance to change. Adopting these strategies can effectively mitigate the barriers to ART adoption, paving the way for its transformative impact on education and training.

The study has some limitations that should be acknowledged. It focused exclusively on the Gauteng province of South Africa, which may restrict the generalisability of the findings to other regions. However, considering the similar socioeconomic conditions across South Africa's provinces, the results apply nationally. Furthermore, the findings may also resonate with other developing countries facing similar barriers to technology adoption. Comparative studies in other regions and countries are recommended to validate and expand upon these findings.

Author Contributions: Conceptualization, O.A. and M.H., J.A., A.O., C.A., and S.A.; methodology, O.A.; validation, O.A., M.H., J.A., A.O., C.A., and S.A.; formal analysis, O.A.; investigation, O.A.; resources, O.A.; data curation, O.A.; writing—original draft preparation, O.A.; writing—review and editing, O.A.; visualization, O.A.; supervision, O.A.; project administration, O.A.; funding acquisition, M.H., J.A., A.O., C.A., and S.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The authors confirm that this study was reviewed and approved by the Ethics and Plagiarism Committee (FEPC) of the Faculty of Engineering and the Built Environment at the University of Johannesburg with approval number UJ_FEBE_FEPC_00702.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The authors confirm that the data supporting the findings of this study are available within the article. Further data that support the findings of this study are available from the corresponding author, OA, upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Akinradewo, O.; Aigbavboa, C.; Oke, A.; Edwards, D.; Kasongo, N. Key requirements for effective implementation of building information modelling for maintenance management. *Int. J. Constr. Manag.* **2022**, *23*, 1902–1910. [CrossRef]
2. Osunsanmi, T.O.; Aigbavboa, C.; Oke, A. Construction 4.0: The Future of the Construction Industry in South Africa. *World Acad. Sci. Eng. Technol. Int. J. Civ. Environ. Eng.* **2018**, *12*, 150–156.
3. Onime, C.; Uhomoibhi, J.; Radicella, S. Chapter 11 MARE: Mobile Augmented Reality Based Experiments in Science, Technology and Engineering. In *Online Experimentation: Emerging Technologies and IoT*, 4th ed.; Restivo, M.T., Cardoso, A., Lopes, A.M., Eds.; International Frequency Sensor Association Publishing: Barcelona, Spain, 2015; pp. 209–227.
4. Chang, G.; Morreale, P.; Medicherla, P. Applications of Augmented Reality Systems in Education. In *Proceedings of the SITE 2010—Society for Information Technology & Teacher Education International Conference*; Gibson, S., Dodge, B., Eds.; Association for the Advancement of Computing in Education (AACE): Anaheim, CA, USA, 2010; pp. 1380–1385.
5. Aghimien, D.; Aigbavboa, C.; Matabane, K. Impediments of the Fourth Industrial Revolution in the South African Construction Industry. In *Collaboration and Integration in Construction, Engineering, Management and Technology*; Ahmed, S.M., Hampton, P., Azhar, S., Saul, A.D., Eds.; Advances in Science, Technology & Innovation: London, UK; Springer: Cham, Switzerland, 2021; pp. 223–228. [CrossRef]
6. Li, X.; Yi, W.; Chi, H.-L.; Wang, X.; Chan, A.P. A critical review of virtual and augmented reality (VR/AR) applications in construction safety. *Autom. Constr.* **2018**, *86*, 150–162. [CrossRef]
7. Deshpande, A.; Kim, I. The effects of augmented reality on improving spatial problem solving for object assembly. *Adv. Eng. Inform.* **2018**, *38*, 760–775. [CrossRef]
8. Radu, I. Augmented reality in education: A meta-review and cross-media analysis. *Pers. Ubiquitous Comput.* **2014**, *18*, 1533–1543. [CrossRef]
9. Diegmann, P.; Schmidt-Kraepelin, M.; Eynden, S.; Basten, D. Benefits of Augmented Reality in Educational Environments—A Systematic Literature Review. *Wirtsch. Proc.* **2015**, *103*, 1542–1556. Available online: http://aisel.aisnet.org/wi2015/103 (accessed on 12 September 2024).
10. Martínez, H.; Skournetou, D.; Hyppölä, J.; Laukkanen, S.; Heikkilä, A. Drivers and Bottlenecks in the Adoption of Augmented Reality Applications. *J. Multimed. Theory Appl.* **2014**, *2*, 27–44. [CrossRef]
11. O'Brien, H.L.; Toms, E.G. Universities of Leeds, Sheffield and York. *J. Am. Soc. Inf. Sci. Technol.* **2008**, *59*, 938–955. [CrossRef]
12. Vasilevski, N.; Birt, J. Analysing construction student experiences of mobile mixed reality enhanced learning in virtual and augmented reality environments. *Res. Learn. Technol.* **2020**, *28*, 1–23. [CrossRef]

13. Ohler, J. Digital Storytelling in the Classroom: New Media Pathways to Literacy, Learning, and Creativity. In *Computers and Composition*; Corwin Press: Thousand Oaks, CA, USA, 2008; Volume 25, pp. 449–452.
14. Mupfunya, F.; Roodt, S.; Mwapwele, S. Readiness analysis of teachers in townships for the use of Augmented Reality in education. In Proceedings of the Fourth African Conference on Information Systems & Technology, Capetown, South Africa, 9–10 July 2018; pp. 126–135.
15. Rodrriguez-Pardo, C.; Hernandez, S.; Patricio, M.Á.; Berlanga, A.; Molina, J.M. An Augmented Reality Application for Learning Anatomy. In *International Work-Conference on the Interplay Between Natural and Artificial Computation*; Springer International Publishing: Elche, Spain, 2015; pp. 359–368. [CrossRef]
16. Rayner, S. Uncomfortable knowledge: The social construction of ignorance in science and environmental policy discourses Uncomfortable knowledge: The social construction of ignorance in science and environmental policy discourses. *Econ. Soc.* **2012**, *41*, 107–125. [CrossRef]
17. Khan, T.; Johnston, K.; Ophoff, J. The Impact of an Augmented Reality Application on Learning Motivation of Students. *Adv. Hum.-Comput. Interact.* **2019**, *2019*, 1–14. [CrossRef]
18. Markets and Markets. Augmented Reality Market Size, Share & Industry Growth Analysis Report by Product by Device Type (Head-mounted Display, Head-up Display), Offering (Hardware, Software), Application (Consumer, Commercial, Healthcare), Technology, and Geography (2021–2026). *Market Research Report*. 2021. Available online: https://www.marketsandmarkets.com/Market-Reports/augmented-reality-market-82758548.html (accessed on 18 September 2024).
19. Alkhattabi, M. Augmented Reality as E-learning Tool in Primary Schools' Education: Barriers to Teachers' Adoption. *Int. J. Emerg. Technol. Learn.* **2017**, *12*, 91–100. [CrossRef]
20. Oke, A.E.; Arowoiya, V.A. Critical barriers to augmented reality technology adoption in developing countries: A case study of Nigeria. *J. Eng. Des. Technol.* **2021**, *20*, 1320–1333. [CrossRef]
21. Afolabi, A.O.; Nnaji, C.; Okoro, C. Immersive Technology Implementation in the Construction Industry: Modeling Paths of Risk. *Buildings* **2022**, *12*, 363. [CrossRef]
22. Nikmehr, B.; Hosseini, M.R.; Martek, I.; Zavadskas, E.K.; Antucheviciene, J. Digitalization as a Strategic Means of Achieving Sustainable Efficiencies in Construction Management: A Critical Review. *Sustainability* **2021**, *13*, 5040. [CrossRef]
23. Knoth, K.; Fufa, S.M.; Seilskjær, E. Barriers, success factors, and perspectives for the reuse of construction products in Norway. *J. Clean. Prod.* **2022**, *337*, 130494. [CrossRef]
24. Gausdal, A.H.; Czachorowski, K.V.; Solesvik, M.Z. Applying Blockchain Technology: Evidence from Norwegian Companies. *Sustainability* **2018**, *10*, 1985. [CrossRef]
25. Adekunle, P.; Aigbavboa, C.; Thwala, D.; Oke, A.; Akinradewo, O. Construction Information Management: The role of Fourth Industrial Revolution Tools. *Hum. Factors Archit. Sustain. Urban Plan. Infrastruct.* **2022**, *58*, 254–261. [CrossRef]
26. Maffea, J. Lack of Resources in Classrooms. *English Department: Research for Change—Wicked Problems in Our World*. Research Commons at Kutztown University. 2020. Available online: https://research.library.kutztown.edu/wickedproblems/38 (accessed on 10 September 2024).
27. Machado, C.G.; Winroth, M.; Carlsson, D.; Almström, P.; Centerholt, V.; Hallin, M. Industry 4.0 readiness in manufacturing companies: Challenges and enablers in manufacturing companies: Challenges and enablers Design increased a architecture of A new methodology to analyze the functional physical Carlsson. In Proceedings of the 52nd CIRP Conference on Manufacturing Systems, Ljubljana, Slovenia, 12–14 June 2019; Centerholt, V., Hallin, M.C., Eds.; Elsevier B.V.: Ljubljana, Slovenia, 2019; pp. 1113–1117. [CrossRef]
28. Malomane, R.; Musonda, I.; Okoro, C.S. The Opportunities and Challenges Associated with the Implementation of Fourth Industrial Revolution Technologies to Manage Health and Safety. *Int. J. Environ. Res. Public Health* **2022**, *19*, 846. [CrossRef] [PubMed]
29. Fernandez, M. Augmented Virtual Reality: How to Improve Education Systems. *High Learn. Res. Commun.* **2017**, *7*, 1–15. [CrossRef]
30. Rejeb, A. The Challenges of Augmented Reality in Logistics: A Systematic Literature Review. *World Sci. News* **2019**, *134*, 281–311.
31. Selvaprasanth, P.; Karthigaipriya, T. Adoption of Virtual Reality in Construction Projects Department of Civil Engineering, Tamil Nadu, India. *J. Univ. Shanghai Sci. Technol.* **2021**, *23*, 476–490. [CrossRef]
32. Asogwa, B.E.; Ezema, I.J. Freedom of access to government information in Africa: Trends, status and challenges. *Rec. Manag. J.* **2017**, *27*, 318–338. [CrossRef]
33. Chauhan, C.; Singh, A.; Luthra, S. Barriers to industry 4.0 adoption and its performance implications: An empirical investigation of emerging economy. *J. Clean. Prod.* **2021**, *285*, 124809. [CrossRef]
34. Choi, M.; Ahn, S.; Seo, J. VR-Based investigation of forklift operator situation awareness for preventing collision accidents. *Accid. Anal. Prev.* **2020**, *136*, 105404. [CrossRef] [PubMed]

35. Schuir, J.; Teuteberg, F. *Understanding Augmented Reality Adoption Trade—Offs in Production Environments from the Perspective of Future Employees: A Choice—Based Conjoint Study, Information Systems and e-Business Management*; Springer: Berlin/Heidelberg, Germany, 2021. [CrossRef]
36. Mallick, S. Augmenting Property Law: Applying the Right to Exclude in the Augmented Reality Universe Augmenting Property Law: Applying the Right to Exclude in the Augmented Reality Universe. *Vand. J. Entertain. Technol. Law* **2020**, *19*, 1057.
37. Mirković, V.; Lukic, J.; Lazarevic, S. Key Characteristics Of Organizational Structure. In Proceedings of the 24th International Scientific Symposium Strategic Management and Decision Support Systems in Strategic Management, Subotica, Republic of Serbia, 17 May 2019; pp. 1–7.
38. Tangi, L.; Janssen, M.; Benedetti, M.; Noci, G. Barriers and Drivers of Digital Transformation in Public Organizations: Results from a Survey in the Netherlands. In *Electronic Government—19th IFIP WG 8.5 International Conference, EGOV 2020, Proceedings*; Pereira, G.V., Janssen, M., Lee, H., Lindgren, I., Bolívar, M.P.R., Scholl, H.J., Eds.; Springer International Publishing: Berlin/Heidelberg, Germany, 2020; pp. 42–56. [CrossRef]
39. O'Hagan, C. Learning Leadership and Technology Enhanced Learning: From Rhetoric to Reality. In *Developing Technology Mediation in Learning Environments*; Bocanet, V., Ed.; IGI Global: Porto, Portugal, 2020; pp. 1–22. [CrossRef]
40. Semenets-Orlova, I.; Klochko, A.; Shkoda, T.; Marusina, O.; Tepliuk, M. Emotional Intelligence as the Basis for the Development of Organizational Leadership During the COVID Period (Educational Institution Case). *Stud. Appl. Econ.* **2021**, *39*, 1–15. [CrossRef]
41. Ramilo, R.; Bin Embi, M.R. Critical analysis of key determinants and barriers to digital innovation adoption among architectural organizations. *Front. Arch. Res.* **2014**, *3*, 431–451. [CrossRef]
42. Bollweg, L.; Lackes, R.; Siepermann, M.; Weber, P. Drivers and barriers of the digitalization of local owner operated retail outlets. *J. Small Bus. Entrep.* **2019**, *32*, 173–201. [CrossRef]
43. Lim, C.P.; Wang, T. A Framework and Self-Assessment Tool for Building the Capacity of Higher Education Institutions for Blended Learning. In *Blended Learning for Quality Higher Education: Selected Case Studies on Implementation from Asia-Pacific*; Lim, C.P., Wang, L., Eds.; UNESCO: Bangkok, Thailand, 2016; pp. 1–38.
44. Chauhan, J.; Taneja, S.; Goel, A. Enhancing MOOC with Augmented Reality, Adaptive Learning and Gamification. In Proceedings of the 2015 IEEE 3rd International Conference on MOOCs, Innovation and Technology in Education, MITE 2015, Amritsar, India, 1–2 October 2015; pp. 348–353. [CrossRef]
45. Lampropoulos, G.; Keramopoulos, E.; Diamantaras, K.; Evangelidis, G. Augmented Reality and Gamification in Education: A Systematic Literature Review of Research, Applications, and Empirical Studies. *Appl. Sci.* **2022**, *12*, 6809. [CrossRef]
46. Van Wart, M.; Roman, A.; Wang, X.; Liu, C. Administrative Leadership Theory: A Reassessment After 10 Years Telematics and Informatics Integrating ICT adoption issues into (e-) leadership theory. *Telemat. Inform.* **2020**, *34*, 527–537. [CrossRef]
47. Ahmad Nawi, H.S.; Abdul-Rahman, A.; Ibrahim, O. Government ICT Project Failure Factors: Project Stakeholders' Views Government ICT Project Failure Factors: Project Stakeholders 'Views'. *J. Res. Innov. Inf. Syst.* **2014**, *2*, 69–77. Available online: http://seminar.utmspace.edu.my/myaisprint/2 (accessed on 18 September 2024).
48. Bassani, G.; Pfister, J.A.; Cattaneo, C. Management accounting change as an amplifier of a leadership dispute: An ethnography of convergent and divergent leader–follower relations. *Account. Audit. Account. J.* **2021**, *34*, 104–134. [CrossRef]
49. Sebok, A.; Mann, R.; Andre, T.; Gronstedt, A.; Chik, K.; Cooley, I.; Shell, D.; Anderson, H. Augmented Reality Applications in Support of Electrical Utility Operations. *Proc. Hum. Factors Ergon. Soc. Annu. Meet.* **2020**, *64*, 1323–1327. [CrossRef]
50. Kim, H.; Kim, T.; Lee, M.; Kim, G.J.; Hwang, J.I. Don't Bother Me: How to Handle Content-Irrelevant Objects in Handheld Augmented Reality. In Proceedings of the 26th ACM Symposium on Virtual Reality Software and Technology, Virtual Event, 1–4 November 2020. [CrossRef]
51. Lee, M.; Bruder, G.; Welch, G. Exploring the Effect of Vibrotactile Feedback through the Floor on Social Presence in an Immersive Virtual Environment. In Proceedings of the 2017 IEEE Virtual Reality (VR), Los Angeles, CA, USA, 18–22 March 2017; pp. 105–111.
52. Pereira, C.S.; Durão, N.; Fonseca, D.; Ferreira, M.J.; Moreira, F. An Educational Approach for Present and Future of Digital Transformation in Portuguese Organizations. *Appl. Sci.* **2020**, *10*, 757. [CrossRef]
53. Durão, N.; Ferreira, M.J.; Pereira, C.S.; Moreira, F. Current and future state of Portuguese organizations towards digital transformation. *Procedia Comput. Sci.* **2019**, *164*, 25–32. [CrossRef]
54. Miller, K.D.; Gomes, E.; Lehman, D.W. Strategy restoration. *Long Range Plan.* **2019**, *52*, 101855. [CrossRef]
55. Etikan, I.; Bala, K. Biometrics & Biostatistics International Journal Sampling and Sampling Methods. *Biom. Biostat. Int. J.* **2017**, *5*, 1–3. [CrossRef]
56. Eekhout, I.; de Vet, H.C.; Twisk, J.W.; Brand, J.P.; de Boer, M.R.; Heymans, M.W. Missing data in a multi-item instrument were best handled by multiple imputation at the item score level. *J. Clin. Epidemiol.* **2014**, *67*, 335–342. [CrossRef] [PubMed]
57. Watkins, M.W. Exploratory Factor Analysis: A Guide to Best Practice. *J. Black Psychol.* **2018**, *44*, 219–246. [CrossRef]
58. Kwak, S.G.; Park, S. Normality Test in Clinical Research. *J. Rheum. Dis.* **2019**, *26*, 5–11. [CrossRef]
59. Varannai, I.; Sasvari, P.; Urbanovics, A. The Use of Gamification in Higher Education: An Empirical Study. *Int. J. Adv. Comput. Sci. Appl.* **2017**, *8*, 1–6. [CrossRef]

60. Schneider, W.J. Concept symbols revisited: Naming clusters by parsing and filtering of noun phrases from citation contexts of concept symbols. *Scientometrics* **2006**, *68*, 573–593. [CrossRef]
61. Armstrong, C.S.; Banerjee, S.; Corona, C. Factor-Loading Uncertainty and Expected Returns. *Rev. Financ. Stud.* **2013**, *26*, 158–207. [CrossRef]