ADOPTABILITY OF AUGMENTED REALITY AS A SUPPLEMENTARY TOOL IN ARCHITECTURE, ENGINEERING, AND CONSTRUCTION EDUCATION IN GHANA

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Abstract

Aim/Purpose-This study examines the adoptability of augmented reality as a supplementary tool in Architecture, Engineering and Construction (AEC) education in Ghana. The research investigates the potential of augmented reality (AR) technology in enhancing AEC education and explores its adoptability within the Ghanaian context. The significance of the study is highlighted, emphasizing the importance of integrating technology in AEC education to bridge the gap between theory and practice.

Methodology- The study used a quantitative research approach. A structured questionnaire for the study was designed from the literature review and administered to students and lecturers in AEC education at Knust. Both purposive and snowball sampling methods were used in this study to obtain a valid and effective overall sample size. The questionnaire was disseminated through Google Forms. Fifty were retrieved and used for the analysis of the study. The statistical tools used for analysis are frequency, percentages,

and mean scores.

Results-The study identifies gaps in the current AEC education system, including limited technology integration, hands-on learning opportunities, lack of awareness among faculty, and the Interdisciplinary Training. The benefits of augmented reality in AEC education are explored, highlighting improved visualization, student engagement, knowledge retention, and critical thinking skills. Implementation challenges, such as cost, technical support, and content availability, are also identified. The conclusion highlights the potential of augmented reality in enhancing AEC education and emphasizes the need for its integration into the curriculum.

Value-The findings of this research contribute to the understanding of augmented reality's adoptability in AEC education in Ghana. By embracing augmented reality technology, educational institutions can enhance the learning experience, bridge the gap between theory and practice, and prepare students for successful careers in the construction industry

Keywords: Adoptability, Augmented reality, Architecture, Engineering, Construction (AEC), education

INTRODUCTION

While the construction of electronic guides often results in the "wrapping" of old material in a new form, traditional schoolbooks do not reflect the source of true knowledge (Sannikov, et al 2015). Students studying Architecture, Engineering, and Construction are becoming less interested in learning, and they are experiencing information overload. The challenge of inspiring students to study Architecture, Engineering and Construction, foster technical innovation, and carry out research and project activity becomes crucial in light of the aforementioned (Delgado et al, 2020). A new technology called augmented reality has the power to fundamentally alter the construction industry (Nassereddine et al., 2022). In addition, to this, skill shortages continue to be a problem in several areas, including the construction industry, which has a high need for trained personnel (Wright et al. 2019). One of the most useful tools for completing the aforementioned goal, according to Iatsyshyn et al. (2020), is the development of interactive instructional material employing augmented reality and 3D visualization and its application in Tertiary education (Rashevska, et al 2020).

2.0 LITERATURE REVIEW

2.1 Overview of AEC education

The education in architecture, engineering, and construction revolves around imparting practical knowledge, with a particular emphasis on the structure and characteristics of three-dimensional (3D) things. Structures such as buildings, bridges, and open spaces are typically associated with information about their various parts, including stress, size, materials, assembly, and construction processes (Poinet, 2020). Throughout several phases, such as conceptual and schematic design, detailed design, construction documentation, fabrication, assembly, and final structure records, construction models have been essential in gathering and defining information. One noteworthy industry trend is the increasing use of various simulation techniques applied to virtual models. These simulations serve educational and practical purposes, such as assessments, drills, instruction, and presentations of suggested fixes. By skillfully fusing virtual designs with their physical attributes, augmented reality (AR) is utilized to satisfy needs for both specialist practice and education while also taking into consideration the unique professional traits of the industry (Getuli et al., 2021). The goal of architectural, engineering, and construction (AEC) education is to prepare students for careers in design, engineering, and construction management. Building and infrastructure design, planning, and construction all depend on these intricate and interconnected disciplines (Safikhani et al., 2022). Offering a curriculum that combines specialized knowledge with a solid foundation of fundamental skills is essential to ensuring that students receive a well-rounded education in the field of architecture, engineering, and construction (AEC) (Aguilar et al., 2023; Chegu Badrinath et al., 2016). Unfortunately, there appears to be a mismatch between what is taught and the actual usage of computer technology by experts in these domains (Bolpagni et al., 2022). The AEC sector is extremely competitive, and businesses that use cutting-edge technology can outperform their rivals. One of the global industries with the quickest rate of growth is construction, and the AEC sector is gradually moving away from traditional methods and towards automation. To facilitate smart and instantaneous interactions among individuals, information, and representations in both physical and virtual realms, it is crucial to introduce and develop various methodologies, methods, and technologies. The AEC sector (Alizadehsalehi et al., 2020) has the potential to revolutionize the planning, execution, and maintenance of building projects. Ghana is making investments to enhance the quality of AEC education in order to fulfill the requirements of its progressing nation (Takyi-Annan, et al., 2023)

2.2 Importance of AEC Education

Professionals who have received education in fields such as architecture, engineering, construction management, and surveying possess a strong foundation. This enables them to tackle complex challenges related to the designing, constructing, and managing of buildings and infrastructure. The importance of safety standards and quality assurance in the construction industry is emphasized in AEC education (Almusaed, et al, 2023). Professionals who have received comprehensive education are more likely to follow safety protocols, building codes, and regulations that ensure the safety of occupants and the durability of structures (Rafsanjani, and Nabizadeh, 2023).

2.2.1 Sustainable Practices

With growing concerns about environmental impact and limited resources, education in the field of AEC places great emphasis on sustainable practices. Professionals are taught how to design structures that conserve energy, use eco-friendly building materials, reduce waste, and incorporate renewable energy sources. (Agbajor, and Mewomo, 2022: Almusaed, et al 2023). AEC professionals trained in sustainable practices contribute to eco-friendly building and infrastructure. (Almusaed, et al. 2023: Zakharova, et al. 2020).

2.2.2 Innovation and Technological Advancements

Education in AEC promotes innovation and motivates the integration of new technologies in the industry. Students get to learn about the latest tools, software, and techniques used in fields such as building information modeling (BIM), virtual reality, drones, and robotics (Safikhani, et al, 2022,). This knowledge empowers professionals to accept technological developments, which in turn enhances effectiveness, precision, and teamwork in the AEC sector (Musarat, et al, 2023).

2.2.3 Collaboration and Interdisciplinary Skills

Education in the architecture, engineering, and construction (AEC) field encourages interdisciplinary collaboration, promoting communication and teamwork among professionals from diverse backgrounds. By working together, architects, engineers, construction managers, and other AEC professionals can integrate their expertise and perspectives to achieve project objectives. This collaborative approach results in better coordination, fewer conflicts, and improved project outcomes. (Indraprastha, 2023).

2.2.4 Economic Development

The AEC industry is crucial in driving economic growth and development. AEC education is essential in producing skilled professionals who drive innovation, create job opportunities, and promote progress in the construction sector. Well-educated AEC experts can effectively contribute to the economic advancement of their communities and nations (Cheng, et al.2016).

2.2.5 Lifelong Learning and Professional Growth

AEC education goes beyond formal degree programs and emphasizes the importance of lifelong learning and continuous professional development. AEC professionals are urged to stay current with the latest industry trends, regulations, and advancements by attending workshops, and seminars, obtaining certifications, and participating in conferences. This ongoing education helps professionals stay up-to-date with changing industry demands and maintain their competence throughout their careers (Hickey, 2023).

2.3 GAPS IN AEC EDUCATION

In recent years, the construction industry has undergone rapid transformations driven by the implementation of new construction standards, particularly the integration of advanced technologies like augmented reality, environmental management, information technology, and building information modeling (Pan and Zhang, 2021). To ensure that construction graduates can effectively navigate the modern construction environment, it is essential for construction educators to undertake appropriate curriculum reforms that bridge the gaps between educational attainment and job requirements (Maki, 2023). According to Brunello et al. (2021), there are two types of gaps or mismatches that can arise between educational attainment and job requirements. Overeducation occurs when educational attainment exceeds job requirements, creating a mismatch. Conversely, underqualification occurs when job requirements surpass educational attainment, leading to another mismatch. Notably, underqualification appears to be a more significant issue since overqualified graduates can still adequately meet job requirements, whereas underqualified graduates struggle without on-the-job training (Wiedner, 2022). In Ghana, as in many other countries, the Architecture, Engineering, and Construction (AEC) sector plays a pivotal role in shaping the built environment. However, the effectiveness of AEC education is subject to various challenges and gaps. To address these gaps and foster a more holistic learning experience, this study aims to assess the potential of augmented reality (AR) technology as a supplementary tool in AEC education. Before evaluating the adoptability of AR technology in the Ghanaian context, it is crucial to identify the existing skill gaps in AEC education. (Datta, et al.,2023: Takyi-Annan, et al.,2023)

2.3.1 Technical Drawing and Drafting

Technical drawing and drafting are fundamental skills in AEC education. These skills enable students to visualize design ideas from two-dimensional representations of three-dimensional spaces (Sami Ur Rehman, et al, 2023). It is often observed that students encounter difficulties in mastering this skill due to the complexity of architectural and engineering drawings. As a result, many educational institutions in Ghana need to develop more effective teaching methods and resources to bridge this gap. (Kumi-Yeboah, et al, 2023)

2.3.2 Technical Knowledge and Proficiency

Technical knowledge and proficiency are essential in AEC education. Students should not only understand theoretical concepts but also be proficient in applying them practically. It is evident that there is a need for curricula that strike a better balance between theory and practical application (Brewer and Cunningham, 2023)

2.3.3 Communication and Teamwork Skills

The AEC sector heavily relies on effective communication and teamwork. These skills are crucial in ensuring the success of construction projects. Many AEC education programs in Ghana have identified gaps in teaching effective communication and fostering teamwork among students (Yamoah Agyemang, 2022).

2.3. 4 Construction Schedules and Cost Estimates

Students often struggle with creating accurate construction schedules and cost estimates. This skill gap can result in project delays and budget overruns. Addressing these issues requires the development of a curriculum that provides students with practical experience in project management (Rahat, et al.,2023).

2.3.5 Integration of Technology

The integration of technology, such as Building Information Modeling (BIM), 3D printing, and virtual reality, is becoming increasingly important in the AEC sector. However, the existing curriculum may not adequately prepare students to harness the full potential of these technologies (Safikhani, et al.,2022).

2.3. 6 Hands-On Learning Opportunities

Hands-on learning opportunities are limited in many AEC programs, depriving students of the practical experience needed for success in the field. Bridging this gap necessitates more investment in practical workshops and laboratories (Blair 2022).

2.3.7. Global Perspective and Diversity and Inclusion

A global perspective is essential in AEC education, exposing students to international standards, practices, and case studies. Additionally, curricula should be designed to prepare students for an industry that values a broad range of perspectives and experiences (Özener 2023).

2.4 AUGMENTED REALITY (AR) IN AEC EDUCATION

Depending on the size of the organization, there are significant differences in the AEC industries' adoption of AR and VR. Medium-sized and small businesses are finding it difficult to stay up with the pace set by large enterprises, who have the resources for technology, in-house content development teams, and equipment (Stentoft et al., 2021). Small businesses are unable to test AR and VR for every use case, therefore they are restricted to simple use cases like design reviews and stakeholder involvement. They must rely on off-the-shelf solutions, which limits their capacity to utilize AR and VR (Schiavi, et al, 2022). In total, six general use cases have been identified (Mojtaba, et al. 2020). The following is a summary of different applications, supported by examples from literature, encompassing (1) Engaging stakeholders, (2) Assisting in design, (3) Reviewing design, (4) Assisting in construction, which includes four subcategories: planning construction, monitoring progress, ensuring construction safety, and providing operational support; and (5) Managing operations (Getuli, et al, 2022).In the fields of architecture, engineering, and construction (AEC), imagery is essential for fostering communication. Thus, it is crucial to make use of augmented reality (AR) and virtual reality (VR) technology. (Oke and Arowoiya, 2022). AEC professionals have been employing these technologies since the 1990s to facilitate the visualization of design, building, and city operations. Augmented Reality (AR) is a technology that overlays computer-generated pictures and information onto the actual world, so increasing the user's view of their immediate environment. This is accomplished by utilizing mobile devices, tablets, or head-mounted displays (Dargan, et al, 2023). On the other hand, virtual reality (VR) is a technological innovation that substitutes the user's actual physical surroundings with a completely computer-generated virtual environment.

This is accomplished through the utilization of devices such as head-mounted displays (HMDs), glasses, and multi-display configurations Uhomoibhi et al. (2020). Architectural and civil engineering (ACE) education is a sort of practice-based knowledge delivery that often links courses to the characteristics and configuration of three-dimensional (3D) things. When constructing a building, bridge, or other structure, it's important to consider various details such as stress, dimensions, materials, assembly, and construction (Messi, et al. 2022). Building models are commonly used to track information from the initial concept design to the final as-built product. Simulations are frequently used with these virtual models to provide training, practice, assessments, and demonstrations of suggested solutions (Rajaratnam, et al., 2021). Augmented reality (AR) is also used to connect the virtual design with the physical property in the real world, making it a valuable tool for educational and specialized practice needs (Sharma, et al, 2022)

The benefits of incorporating Augmented Reality (AR) into an ACE education curriculum are significant and can be classified into two categories: general pedagogies and domain-specific learning. General pedagogies encompass improvements in student interest, performance, and motivation, as reported by (Czok, et al 2023). On the other hand, domain-specific learning refers to the enhancement of graphic competencies and spatial skills among students. These advantages demonstrate the potential of AR technology to combine physical attributes with designated information, which can be easily manipulated without the need for markers (Darwish, et al, 2023). Augmented reality (AR) is highly useful when concluding projects, presentations, and reports that contain both real architectural models and 3D virtual models, according to Schranz et al. (2021).

2.5 Teaching Methods

These instructional strategies include all the necessary elements to replicate professional practice situations that students might encounter in the real world. Three basic elements are included in these scenarios: tasks, roles, and locations. These elements together define a job. For example, students might visit a building site, play the part of a job inspector, or check equipment. Three categories of AR teaching approaches have been recognized for ACE education (Fotia and Houda, 2023). The initial category is commonly known as "highlighting the roles." Within this approach, students adopt various roles within an augmented reality system and actively participate in conversation and discourse with one another. The primary emphasis is on fostering interactions among pupils (Fotia and Houda, 2023).

The second category is referred to as "highlighting the locations." Students in this context explore non-conventional learning settings and employ augmented reality (AR) technology to carry out their educational activities in designated outdoor areas (Diao and Shih, 2019). The third category is referred to as "prioritizing the task." Students employ augmented reality (AR) to accomplish educational assignments, which might be in the form of games or direct interaction. In contrast to the other two teaching methods, this strategy does not entail the categorization or assignment of students into distinct roles, and the majority of the research conducted using this approach took place indoors (Corno, 2023).

Out of the instructional approaches that were found, fourteen studies utilized the "emphasize the task" approach, whereas four publications utilized the "emphasize the locations" approach. Nevertheless, no scholarly articles were discovered that expressly employed the "emphasize the roles" approach, most likely because there is a lack of grading standards that are tailored to roles (Pan and Zhang, 2021). The remaining three publications, which may consist of literature reviews or studies that do not fit into any certain category, are labeled as "others." The quantity of works employing the "emphasize the task" pedagogical approach was not specified (Botha et al., 2023).

3.0 RESEARCH METHODOLOGY

3.1 Research method

Quantitative research methods are used, since the study seeks to collect a large amount of data from a large sample size in a short amount of time. According to Kothari (2004), a quantitative research strategy entails the collection of quantitative data, which is subsequently subjected to rigorous, formal analysis through a series of steps. Survey Research is used for the Study based on the following rationales. Surveys entail the collection of data from participants through the use of questionnaires and interviews. The survey collects outcomes in a standardized and organized manner, using statistically selected samples to minimize any bias and ensure the results are representative of the greater community.

3.2 **Questionnaire design**

Closed-ended questionnaires were designed from a literature review and used to gather primary data through Google Forms. Closed-ended questionnaires are not only easier to administer but are notable for higher response rates and ease of coding (Dawson, 2007).

3.3 Respondents and information collection

The study population comprises lecturers and students from the Architecture, Construction, and Engineering departments of Kwame Nkrumah University of Science and Technology because students and lecturers are key stakeholders in the educational context, where the study is likely to take place.

The study included both purposive and snowball sampling approaches to provide a valid and efficient overall sample size. The study used the Snowball-Sampling-Technik to first contact a small number of potential participants, who were then asked to recommend organizations or individuals that meet certain criteria. The purposive sample technique was then used to choose study participants.

3.4 Data discovery and analysis

Following the collection of the questionnaires, the quantitative data was cleaned, coded, and entered in the statistical package for social sciences (SPSS)-application in preparation for further analysis and interpretation. The analytical tools for the study were Descriptive Statistics (simple frequencies and mean score). Descriptive statistics enable researchers to compare different groups or conditions based on key variables.

3.5 Piloting and Pretesting of Questionnaires

To ensure the reliability and comprehensibility of the questionnaires that are employed in this study. The piloting and pretesting of these instruments were conducted to represent a crucial preparatory step aimed at gaining valuable insights and feedback from both lecturers and peers. Pretesting: Confirm that the questionnaire can be completed within the anticipated timeframe (less than 10 minutes).

3.6 Ethical Considerations in Research

Following ethical standards, all individuals participating in this study received comprehensive and lucid information about the research. To ensure the confidentiality and privacy of participants, all collected data, encompassing personal particulars and responses, will undergo anonymization and secure storage.

To ensure validity and reliability in research, Cronbach's alpha is used to assess the internal consistency of the scale or instrument.

4.0 RESEARCH FINDINGS

4.1 Demographic data

Table *4.1. 1 Academic study level*

	Frequency	Percent
BSc	32	64.0
MPhil	1	2.0
MSc	17	34.0
Total	50	100.0

Source: field data, 2023

This frequency distribution provides an overview of the respondents' levels of academic study. 64 percent of the sample has a BSc degree, whereas the percentages of those with MPhil (2%) and MSc (34%), respectively, are lower.

Table 4. 1.2 Program of study

	Frequency	Percent
Architect	5	10.0
Civil Engineering	2	4.0
Construction Management	18	36.0

	Quantity Surveying	25	50.0
	Total	50	100.0

Source: field data, 2023

This frequency distribution provides an overview of how different occupational types or professions are distributed among the respondents in the dataset. The majority of the respondents is comprised of individuals in roles associated to quantity Surveying (50%) and construction management (36%). Lower percentages are present. Architecture": Five people, or 10% of the sample as a whole, are employed in the architectural area. “Civil Engineering": Two people, or 4% of the sample as a whole, work in the field of civil engineering

4.2 MEAN SCORE ANALYSIS OF GAPS IN ARCHITECTURE, ENGINEERING, AND CONSTRUCTION (AEC) EDUCATION METHODS

The table presents the results of a survey aimed at identifying the gaps in Architecture, Engineering, and Construction (AEC) education methods. The respondents were asked to rate their level of competence in various skills on a scale from 1 to 5, with 1 being "Very Incompetent" 2 being "Incompetent" 3 being "Moderate competent" 4 being "competent" and 5 being "Very Competent."

Table 4. 2.1 gaps in Architecture, Engineering, and Construction (AEC) education methods

	N	Mean	Std. Deviation
	Statistic	Statistic	Statistic
Cost estimates	50	3.9000	1.03510
Problem-solving skills	50	3.8400	.99714
Communication and teamwork skills	50	3.8400	.88893
Diversity and Inclusion (curriculum prepares students for an industry that values a broad range of perspectives and experiences)	50	3.7400	1.12141
soft skills	50	3.7000	.78895
Construction schedules	50	3.7000	1.12938
Professional Ethics	50	3.6800	1.15069
Technical knowledge and proficiency	50	3.6200	1.02798
Technical Drawing and Drafting:	50	3.5800	1.16216
Integration of Technology (Building Information Modeling (BIM), 3D printing, and virtual reality)	50	3.5600	1.01338

Visualizing design ideas from two-dimensional designs that depict a three-dimensional space	50	3.4800	1.09246
Continual Learning and Adaptability	50	3.4600	1.18166
Hands-On Learning Opportunities	50	3.3800	1.15864
Interdisciplinary Training	50	3.3000	1.26572
Global Perspective (exposed to international standards, practices, and case studies)	50	3.2200	1.09339
Industry Partnerships	50	3.0200	1.13371

Source: field data, 2023

The major gaps identified in AEC education includes: industry partnership, global perspective and diversity and inclusion, Interdisciplinary Training, hands-on learning opportunities, continual learning and adaptability, integration of technology etc. A global perspective is essential in AEC education, exposing students to international standards, practices, and case studies. Additionally, curricula should be designed to prepare students for an industry that values a broad range of perspectives and experiences (Özener 2023). Hands-on learning opportunities are limited in many AEC programs, depriving students of the practical experience needed for success in the field.

Bridging this gap necessitates more investment in practical workshops and laboratories (Blair 2022). The integration of technology, such as Building Information Modeling (BIM), 3D printing, and Augmented reality/virtual reality, is becoming increasingly important in the AEC sector. However, the existing curriculum may not adequately prepare students to harness the full potential of these technologies (Safikhani, et al.,2022). In addition, respondents rated their competence in cost estimates at an average of 3.9, indicating a moderate level of competence. This suggests that there might be room for improvement in teaching students how to accurately estimate costs in the AEC field. As a result, many educational institutions in Ghana need to develop more effective teaching methods and resources to bridge this gap.

Problem-solving skills: The average rating for problem-solving skills was 3.84, again indicating a moderate level of competence. Enhancing problem-solving abilities is essential in the AEC industry, where complex challenges often arise. Communication and teamwork skills: Respondents rated their competence in communication and teamwork skills at 3.84. Effective communication and collaboration are crucial in AEC projects, and this rating suggests that there is room for improvement in teaching students these skills.

Diversity and Inclusion: The average rating for diversity and inclusion was 3.74. This indicates that the curriculum may not adequately prepare students for an industry that values a broad range of perspectives and experiences. There is a need to incorporate more inclusive practices and perspectives in AEC education. Soft skills: soft skills, which encompass interpersonal skills, emotional intelligence, and adaptability, received an average rating of 3.7. Developing these skills is essential for success in the AEC industry, and the rating suggests that there is room for improvement in teaching and emphasizing soft skills in education programs.

Construction schedules: The average rating for competence in construction schedules was 3.7. This indicates that there may be gaps in teaching students how to effectively plan and manage construction timelines. Overall, the survey results highlight the need for AEC education programs to focus on enhancing skills related to cost estimates, problem-solving, communication, teamwork, diversity and inclusion, soft skills, construction schedules, and various other areas to better prepare students for the demands of the industry. By addressing these gaps, educators can help bridge the divide between academic knowledge and practical application in the AEC field.

4.3 POTENTIAL OF AUGMENTED REALITY (AR) AS A SUPPLEMENTARY TOOL IN IMPROVING ARCHITECTURE, ENGINEERING, AND CONSTRUCTION (AEC) EDUCATION

4.3.1 Reliability statistics

The reliability statistics provided in this context indicate the internal consistency or reliability of a set of items or measures.

Table 4.3.1 Reliability statistics objective 2

Cronbach's Alpha	N of Items
.940	11

Source: field data, 2023

The Cronbach's Alpha coefficient in this instance is.940, a very high value. Greater internal consistency is indicated by higher values of the coefficient, which range from 0 to 1. The 11 items or measures used in this study have an Alpha coefficient of .940, which indicates that they are very consistent and trustworthy in measuring the relevant concept.

4.3.2 Potential of Augmented Reality (AR) As A Supplementary Tool in Improving Architecture, Engineering, And Construction (AEC) Education

The data provided presents the results of a survey aimed at assessing the perceived potential of augmented reality (AR) as a supplementary tool in improving Architecture, Engineering, and Construction (AEC) education. The respondents were asked to rate the level of enhancement on a scale from 1 to 5, with 1 representing the lowest level and 5 representing the highest level of improvement.

Table 4.3.2 Potential of Augmented Reality (AR) As A Supplementary Tool in Improving Architecture, Engineering, And Construction (AEC) Education

	N	Mean	Std. Deviation	Std. Error Mean
Perceived improvement in engagement	50	3.4600	1.03431	.14627

Perceived improvement in comprehension of AEC concepts	50	3.5000	.95298	.13477
Perceived improvement in retention of knowledge	50	3.7200	1.06981	.15129
Perceived improvement in problem-solving skills	50	3.8400	.86567	.12242
Perceived improvement in collaboration and teamwork skills	50	3.9000	.86307	.12206
Skills Development Enhancement	50	3.8800	1.00285	.14182
Improvement in technical skills	50	3.8400	.97646	.13809
Improvement in hands-on or practical skills (e.g., construction techniques)	50	3.7800	1.01599	.14368
Improvement in communication and presentation skills	50	3.8200	1.04374	.14761
Improvement in interdisciplinary skills (e.g., working with architects, engineers, and contractors)	50	3.9400	1.01840	.14402
Improvement in critical thinking and decision-making skills	50	3.8200	.96235	.13610

Source: field data,2023

Perceived improvement in engagement: The respondents rated the perceived improvement in engagement with AR as 3.46 on average. This suggests that AR has the potential to moderately enhance student engagement in AEC education as opined by (Delgado, et al. 2020). Perceived improvement in comprehension of AEC concepts: The average rating for the perceived improvement in comprehension was 3.5. This indicates that AR has the potential to moderately enhance the understanding of AEC concepts among students as asserted by (Dargan, et al, 2023). Perceived improvement in retention of knowledge: Respondents rated the perceived improvement in retention of knowledge with AR at an average of 3.72. This suggests that AR has the potential to significantly improve the retention of AEC knowledge among students. Perceived improvement in problem-solving skills: The average rating for the perceived improvement in problem-solving skills was 3.84. This indicates that AR has the potential to significantly enhance problem-solving abilities in the context of AEC education. Perceived improvement in collaboration and teamwork skills: Respondents rated the perceived improvement in collaboration and teamwork skills with AR at an average of 3.9. This suggests that AR has the potential to significantly enhance collaboration and teamwork among AEC students. Skills Development Enhancement: The average rating for skills development enhancement with AR was 3.88. This indicates that AR has the potential to significantly enhance the development of various skills in AEC education. Improvement in technical skills: The average rating for the improvement in technical skills was 3.84. This suggests that AR has the potential to significantly improve technical skills in the AEC field. Improvement in hands-on or practical skills: Respondents rated the improvement in hands-on or practical skills with AR at an average of 3.78. This indicates that AR has the potential to significantly enhance practical skills, such as construction techniques, in AEC education. Improvement in communication and presentation skills: The average rating for improvement in communication and presentation skills was 3.82. This suggests that AR has the potential to significantly enhance communication and presentation abilities among AEC students (Oke and Arowoiya, 2022). Improvement in interdisciplinary skills: Respondents rated the improvement in interdisciplinary skills with AR at an average of 3.94. This indicates that AR has the potential to substantially enhance interdisciplinary skills, such as working with architects, engineers, and contractors (Getuli, et al,2022). Improvement in critical thinking and decision-making skills: The average rating for improvement in critical thinking and decision-making skills was 3.82. This suggests that AR has the potential to significantly enhance critical thinking and decision-making abilities in the AEC field Czok, et al (2023). Overall, the data suggests that respondents perceive augmented reality (AR) as having the potential to enhance various aspects of AEC education. AR shows promise in improving engagement, comprehension, retention of knowledge, problem-solving skills, collaboration and teamwork, skills development, technical skills, hands-on or practical skills, communication and presentation skills, interdisciplinary skills, and critical thinking and decision-making skills.

4.4 ADOPTABILITY OF AR TECHNOLOGY IN THE CONTEXT OF AEC EDUCATION IN GHANA

4.4.1 Reliability statistics

Table 4.4.3 Reliability Statistics objective 3

Cronbach's Alpha	N of Items
.910	15

Source: field data, 2023

The Cronbach's Alpha coefficient is .910, which is a very high value. Cronbach's Alpha has a range of 0 to 1, with values nearer 1 denoting more dependability in internal consistency. Typically, a Cronbach's Alpha above .70 is considered acceptable, while values above .80 are considered good, and values above .90 are considered excellent.

4.4.2 Mean Score Ranking for Adoptability of AR Technology in The Context of AEC Education in Ghana

The results of the questionnaire provide insights into the perceived adoptability of AR technology in the context of AEC education in Ghana, considering factors such as infrastructure, accessibility, and affordability. The results are based on the responses of 50 participants.

Table 4.4.1 Mean Score Ranking for Adoptability of AR Technology in The Context of AEC Education in Ghana

	N	Mean	Std. Deviation
Network Bandwidth	50	3.08	.922
Location-Based Services:	50	3.06	.956
Cloud-Based Services	50	3.02	.958
Training and Tutorials:	50	2.98	1.020
User Interface Accessibility	50	2.94	.818
Power Supply	50	2.92	1.047
App Stores and Marketplaces	50	2.86	.990
Hardware Compatibility	50	2.86	1.030
Cross-Platform Compatibility	50	2.82	.962
Free or Open-Source Alternatives	50	2.80	.990
Device Availability:	50	2.68	1.077
Subscription Models	50	2.58	.835
Cost of Data Plans	50	2.42	1.108
Total Cost of Ownership	50	2.34	1.002
Cost of AR Devices	50	2.00	.926

Source: field data,2023

1. **INFRASTRUCTURE READINESS:**

Network Bandwidth: The average score of 3.08 indicates a moderate level of readiness for network bandwidth in integrating AR technology. Location-Based Services: The average score of 3.06 suggests a moderate level of support for location-based services.
Cloud-Based Services: The average score of 3.02 indicates a moderate availability of cloud-based services. Training and Tutorials: The average score of 2.98 suggests a moderate availability of training and tutorials. User Interface Accessibility: The average score of 2.94 indicates a moderate level of accessibility to the user interface. Power Supply: The average score of 2.92 suggests a moderate reliability of the power supply. App Stores and Marketplaces: The average score of 2.86 indicates a moderate selection of apps in stores and marketplaces.
Hardware Compatibility: The average score of 2.86 suggests a moderate level of compatibility with hardware. Cross-Platform Compatibility: The average score of 2.82 indicates a moderate level of compatibility across platforms. Free or Open-Source Alternatives: The average score of 2.80 suggests a moderate availability of free or open-source alternatives (Alzubaidi et al., 2023).

2. **ACCESSIBILITY OF AR DEVICES AND APPLICATIONS:**

Device Availability: The mean score of 2.68 suggests a limited availability of AR devices. Subscription Models: The mean score of 2.58 indicates a moderate availability of subscription models for AR technology. Cost of Data Plans: The mean score of 2.42 suggests that data plans for AR technology are moderately priced. Total Cost of Ownership: The mean score of 2.34 indicates a moderate total cost of ownership for AR technology. Cost of AR Devices: The mean score of 2.00 suggests that AR devices are moderately priced. (Xu, et al,2022).
Overall, the results indicate that there is room for improvement in various aspects related to the adoptability of AR technology in AEC education in Ghana. Network bandwidth, location-based services, and cloud-based services seem to have a relatively higher level of readiness compared to other factors. However, areas such as device availability, subscription models, and cost-related factors need attention to enhance the affordability and accessibility of AR technology in the Ghanaian context. It's important to note that these results are based on self-reported perceptions and may not necessarily reflect the actual state of infrastructure, accessibility, and affordability (Yang, et al,2022).

5.0 CONCLUSION

In conclusion, this research has provided insights into the adoptability of augmented reality as a supplementary tool in AEC education in Ghana. The findings indicate the potential of AR to enhance various aspects of AEC education and highlight the need for further exploration and implementation. By addressing the identified challenges and implementing the recommended strategies, educational institutions can embrace AR technology and create a more immersive and effective learning environment for students in the AEC field. The future of AEC education in Ghana can be shaped by leveraging the benefits of augmented reality to foster innovation, collaboration, and sustainable practices in the construction industry.

6.0 RECOMMENDATION

Building upon the findings of this research, the following recommendations are proposed to further explore and enhance the adoptability of augmented reality as a supplementary tool in AEC education. Professional Development and Training: Educational institutions should provide professional development programs and training opportunities for faculty members to enhance their understanding and proficiency in using AR tools and teaching methods. This will help bridge the knowledge gap and promote effective integration of AR into the curriculum.

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