



EFFECT OF AUGMENTED REALITY (AR) TOOLS ON LOW ACHIEVING STUDENTS' ENGAGEMENT IN MATHEMATICS IN ABA EDUCATION ZONE

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Abstract

Amidst students' perception of Mathematics as abstract and difficult, augmented reality (AR) offers a dynamic and interactive instructional approach to enhance learning engagement. Therefore, this study examined the effect of Augmented Reality (AR) tools on student engagement in Mathematics in the Aba Education Zone, Abia State, Nigeria. Two research questions and two hypotheses guided this study. The hypotheses were tested at 0.05 level of significance. The study adopted a one-group pretest-posttest quasi-experimental design. A sample of 60 Senior Secondary School Two (SS2) students identified as low-achievers was drawn from a population of 9,274 SS2 students using a multistage sampling technique. The Mathematics Engagement Scale (MES) with a reliability coefficient of 0.85, was used for data collection. Mean, standard deviation, and paired t-tests were used for data analysis. Results showed that AR significantly enhanced student engagement. The study recommended integrating AR into Mathematics teaching to support low-achieving learners and promote inclusive, technology-enhanced learning.

Keywords: Augmented Reality, Low Achievement, Mathematics Education, Student Engagement,

Introduction

Mathematics remains one of the core subjects essential for academic and professional success. In Nigeria, particularly within the Aba Education Zone, students' achievement in Mathematics has consistently below national expectations, with low-achieving students making up a significant portion of those struggling to meet minimum proficiency levels. Mathematics is foundational to science, technology, engineering, and innovation, yet it remains one of the most challenging subjects for secondary school students, especially in Nigeria (Eze, 2020; WAEC, 2023). Poor achievement in Mathematics among low-achieving students is a critical concern, as it not only affects their academic progression but also limits their access to science, technology, engineering, and mathematics (STEM) career pathways.

Low-achieving students in Mathematics are those students who consistently achieve below expected academic standards in Mathematics. Low-achieving students show persistent difficulties in understanding basic concepts, often relying on rote memorization and exhibiting low confidence and mathematics anxiety (Ibe & Umeh, 2024). These students often experience



challenges that are both academic and non-academic in nature, affecting their ability to thrive in mathematics classrooms (Onuoha & Ikwuagwu, 2021). According to Ndukwe and Okafor (2022), the low-achieving students in secondary school in Aba Education Zone lack basic arithmetic and problem-solving skills, which makes it difficult for them to understand higher-level topics taught at the senior secondary level. These students often fail to make connections between mathematical concepts and real-life applications, resulting in disengagement and loss of interest. This assertion was buttressed by Ezeanya and Chima (2024) who revealed that many students in Aba Education Zone develop negative attitudes towards Mathematics due to repeated failure, unsupportive classroom environments, and low students' engagement.

One of the major challenges contributing to poor academic achievement in Mathematics is the low student engagement in the classroom during Mathematics class (Johnson et al., 2023). Student engagement is a multidimensional construct encompassing behavioral engagement (such as participation and sustained effort), emotional engagement (interest, curiosity, and enjoyment), and cognitive engagement (mental investment and self-regulation in learning) (Okoye & Lin, 2021; Mensah & Zhao, 2023). Student engagement encompasses the attention, curiosity, interest, and motivation that students exhibit during the learning process, influencing how they interact with academic content (Ngugi & Torres, 2021). In Mathematics education, engagement is particularly crucial as it empowers students to solve complex problems, develop positive learning attitudes, and strengthen conceptual understanding (Obasi & Kim, 2024). Despite curriculum reforms, innovative instructional methods, and targeted interventions, low engagement among underperforming students continues to persist (Ahmed et al., 2020). This persistent low students' engagement has led to growing interest in exploring how emerging technologies—particularly immersive technologies like Augmented Reality (AR)—can be leveraged to revitalize students' engagement and improve academic outcomes (Lee et al., 2022).

Augmented Reality (AR) is an interactive technology that overlays computer-generated content—such as 3D models, images, and videos—onto the real-world environment through devices like smartphones, tablets, or AR headsets (Martinez, 2021). Unlike virtual reality, which creates a fully artificial space, AR enhances real-world settings and is especially effective in education by making abstract concepts more tangible (Chukwu & Zhang, 2023). In the Mathematics classroom, AR can support deeper students' engagement by enabling the visualization of geometric figures, algebraic models, and dynamic simulations. These gamified, problem-solving environments promote interest, participation, and interactivity



(Salami et al., 2024). Chen et al., (2023) observed that AR-supported instruction improved mathematical reasoning and reduced learners' anxiety levels, especially among low-performing students. Studies have shown that Augmented Reality (AR) can positively influence all three dimensions of engagement. For example, Ibrahim and Park (2022) reported that students using AR in Mathematics classrooms demonstrated heightened curiosity, longer attention spans, and greater involvement during learning tasks.

By integrating AR into Mathematics teaching, educators can design immersive learning experiences that help low-achieving students understand complex and abstract concepts more effectively. This active learning approach allows students to explore virtual content, receive real-time feedback, and monitor their own learning progress, which has been shown to significantly enhance cognitive, emotional, and behavioral engagement (Okafor & Lee, 2025). The Aba Education Zone in Abia State, Nigeria, is predominantly urban-industrial but also includes several urban and rural communities. Despite its strategic location and economic relevance, the zone continues to face numerous educational challenges, including overcrowded classrooms, under-resourced schools, and limited access to digital infrastructure, particularly in rural areas (Abia State Ministry of Education, 2024). These systemic issues have created disparities in the quality of instruction and learning outcomes across urban and rural schools within the zone (Nwankwo & Bello, 2022). In light of these challenges, Augmented Reality (AR) presents a promising, low-cost instructional innovation that can be deployed using affordable smartphones or tablets, many of which are already in use by students for communication and informal learning (Chinedu & Wang, 2023).

Augmented Reality has the potential to enhance student engagement, especially in Mathematics, by making abstract concepts more interactive and accessible. However, most existing studies on AR integration in education have focused on well-resourced urban settings, often overlooking low-achieving students in hybrid zones like Aba, where both urban and rural learning environments co-exist. However, the adaptability of AR technology offers a promising solution. Affordable smartphones and tablets—already in use by many students—can serve as practical platforms for deploying AR applications, making technology-enhanced learning feasible even in resource-constrained environments (Obinna & Li, 2025). Accordingly, this study determines the effect of AR on the engagement of low-achieving Mathematics students in Aba Education Zone.



Statement of the Problem

Despite numerous interventions, low students' engagement and achievement in mathematics persist across Nigerian secondary schools. Traditional instructional methods often fail to capture the interest of low-achieving students, resulting in disinterest and academic failure. There is a growing need for evidence-based, technology-enhanced instructional strategies that can re-engage struggling learners. While research continues to highlight the benefits of AR in improving learning outcomes, there is a limited body of empirical evidence on its effectiveness in mixed urban-rural educational contexts with infrastructural constraints, particularly within the Aba Education Zone. This study aims to fill that gap by investigating how AR can be effectively utilized to improve Mathematics engagement among low-achieving students across both urban and rural schools. This study addresses the question: What is the effect of augmented reality tools on the engagement of low-achieving students in mathematics in Aba Education Zone?

Purpose of the Study

The purpose of this study is to determine the effect of augmented reality on low-achieving students' engagement in Mathematics. Specifically, the study aims to determine:

1. The mean student engagement scores before and after the use of AR in Mathematics instruction.
2. The mean student engagement scores of urban and rural students before and after the use of AR in Mathematics instruction.

Research Questions

The following questions guided the study.

1. What is the difference in mean student engagement scores before and after the use of AR in Mathematics instruction?
2. What are the differences in the mean student engagement scores of urban and rural students before and after the use of AR in Mathematics instruction?

Hypotheses

The following hypotheses were formulated and tested 0.05 level of significant.

1. There is no significant difference between the mean student engagement scores before and after the use of AR in Mathematics instruction.
2. There is no significant difference between the mean student engagement scores of urban and rural students before and after the use of AR in Mathematics instruction.



Methods

A quasi-experimental one-group pretest-posttest design was adopted. This design allowed the researcher to measure the engagement level before and after the AR intervention without the use of a control group (Creswell & Creswell, 2018). The effect of the treatment on the dependent variable is assessed at the end of the intervention and is determined by the difference in the level of the phenomenon before and after the treatment. In other words, the effect of the treatment is calculated by subtracting the pre-treatment level of the phenomenon from the post-treatment level. The design is symbolically represented in Figure 1.

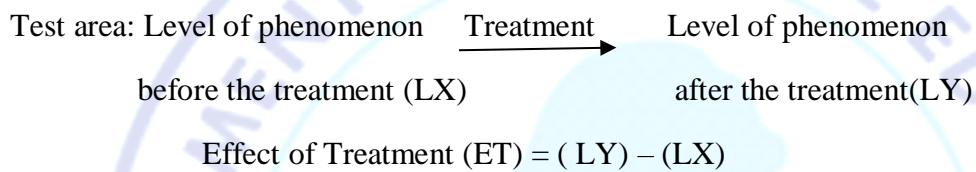


Figure 1: Design of the Experiment

The population consisted of 2077 SS3 students identified as low achievers in Mathematics in Aba Education Zone. To identify low-achieving students, the Centralized Promotion Examination (CPE) results were obtained from the Education Resource Centre in Umuahia. The data focused on students' Mathematics scores for the 2024/2025 academic session. Students who scored below the established benchmark of 40% were categorized as low achievers (Ezeanya & Chima, 2024; Ndukwe & Okafor, 2022). Subsequently, a Diagnostic Mathematics Test was administered to those students, now in SS3, to determine their current ability levels. For sample selection, the following a multistage sampling technique involving stratified, simple random sampling and purposive techniques was adopted to ensure adequate representation and fairness across the Aba Education Zone. The Aba Education Zone consists of nine Local Government Areas which were stratified into three Aba, Isiala Ngwa, and Ukwa, to ensure that each LGA was represented in the study.

At the second stage, from the stratified LGAs, a list of 87 public senior secondary schools was obtained. Using purposive sampling, four schools were selected from each stratum, based on the following criteria: availability of Senior Secondary 2 (SS3) classes, functional mathematics departments with qualified mathematics teachers, availability of ICT facilities to support enriched virtual and flipped learning, administrative approval to participate in the research. This yielded a total of 12 secondary schools—four per LGA. From the selected public senior secondary schools, one school was randomly selected from each stratum. This yielded a total of three secondary schools. To minimize interference with normal school



routines, intact SS3 classes were used in the study. Within each school, one intact class was randomly selected through simple random sampling using simple balloting. Each group consisted of approximately 20 students, yielding a total sample of 60 students. Therefore, a sample of 60 students from three randomly selected public secondary schools was used. The Mathematics Engagement Scale (MES), adapted from Fredricks et al. (2004), was modified for this study. The original instrument had 20 items, but five were removed after expert review for being outside the study's focus.

The final instrument consisted of two sections: Section A gathered respondents' bio-data, while Section B assessed student engagement before and after treatment using a 14-item structured questionnaire. It employed a four-point Likert scale: Strongly Agree (4 points), Agree (3 points), Disagree (2 points), and Strongly Disagree (1 point). Positively worded items were scored from 4 to 1, and negatively worded items were reverse scored. Students' scores were calculated by summing their responses. A score of 2.5 or above is considered acceptable and indicates that the respondent agrees with the statement, suggesting that Augmented Reality (AR) enhanced his or her engagement in Mathematics for the given item. Scores below 2.5 reflect disagreement with the item, indicating that AR did not enhance the respondent's engagement in Mathematics. A minimum score of 35 (62.5%) out of a maximum score of 56 (100%) is the benchmark for determining enhanced engagement in Mathematics.

The instrument was validated and yielded a reliability coefficient of 0.87, calculated using Cronbach's Alpha reliability method. Prior to the commencement of the treatment, MES was administered to the students as a pretest. Thereafter, they were taught selected SS3 Mathematics topics (e.g., geometry, algebra (word problems) using AR tools for four weeks by the regular teachers who were coordinated for this experiment. The lessons involved interactive visualizations using AR apps and devices (GeoGebra AR, CoSpaces Edu, and Merge Edu) to teach Mathematics. For example, in teaching solid shapes, the teachers used Merge Edu app. Instead of drawing pyramid, cubes and cylinders on the board, students use an AR app on their phones to project 3D shapes onto their desks. With the Merge Edu app, students rotated and explored the cone, pyramid, cylinder virtually. Students understood the difference between shapes better by seeing all angles and interacting with the objects. At the end of the treatment, the posttest MES was then administered. Mean and standard deviation were used to answer the research question whereas paired sample t-test was used to test the hypotheses at 0.05 level of significance.



Result

Research Question One

What is the difference in mean student engagement scores before and after the use of AR in Mathematics instruction?

Table 1. Effect of Treatment and Mean Student Engagement Scores

S/N	Pre Test Score(LX)	Post Test Score(LY)	Gain (ET) = (LY) – (LX)
1.	19	45	+26
2	21	42	+21
3	23	47	+24
4	21	42	+21
5	25	45	+20
6	22	40	+18
7	19	49	+30
8	23	45	+22
9	25	44	+19
10	22	41	+19
11	17	43	+26
12	23	45	+22
13	25	46	+21
14	26	47	+21
15	27	47	+20
16	28	46	+18
17	23	42	+19
18	24	41	+17
19	25	53	+28
20	18	49	+31
21	19	45	+26
22	20	38	+18
23	20	40	+20
24	25	46	+21
25	18	39	+21
26	24	40	+16
27	25	43	+18
28	26	45	+19
29	21	42	+21
30	27	44	+17
31	28	47	+19
32	21	41	+20
33	23	43	+20
34	18	39	+21
35	19	40	+21
36	21	41	+20
37	18	38	+20
38	21	43	+22
39	20	39	+19
40	23	45	+22



41	25	46	+21
42	25	43	+18
43	21	40	+19
44	24	41	+17
45	24	42	+18
46	21	45	+24
47	26	41	+15
48	24	45	+21
49	24	41	+17
50	21	42	+21
51	23	48	+25
52	25	39	+14
53	25	35	+10
54	21	36	+15
55	18	37	+19
56	19	38	+19
57	25	39	+14
58	18	40	+22
59	19	37	+18
60	18	39	+21
Mean	22.32	42.52	+20.20

Table 1 shows that the mean student engagement score before exposure to AR was 22.32. After exposure to AR-based instruction, the mean engagement score increased to 42.52. A careful comparison of the pre-intervention and post-intervention scores indicates that students demonstrated a notably higher level of engagement following the integration of AR in Mathematics instruction.

Research Question Two

What are the differences in the mean student engagement scores of urban and rural students before and after the use of AR in Mathematics instruction?

Table 2. Effect of Treatment and Mean Student Engagement Scores of Urban and Rural Students

S/N	URBAN			RURAL		Gain (ET) = (LY) – (LX)
	Pretest	Pos ttest	Gain = (LY) – (LX)	Pretest	Posttest	
1	19	45	+26	28	47	+19
2	21	42	+21	21	41	+20
3	23	47	+24	23	43	+20
4	21	42	+21	18	39	+21
5	25	45	+20	19	40	+21
6	22	40	+18	21	41	+20
7	19	49	+30	18	38	+20
8	23	45	+22	21	43	+22
9	25	44	+19	20	39	+19
10	22	41	+19	23	45	+22

11	17	43	+26	25	46	+21
12	23	45	+22	25	43	+18
13	25	46	+21	21	40	+19
14	26	47	+21	24	41	+17
15	27	47	+20	24	42	+18
16	28	46	+18	21	45	+24
17	23	42	+19	26	41	+15
18	24	41	+17	24	45	+21
19	25	53	+28	24	41	+17
20	18	49	+31	21	42	+21
21	19	45	+26	23	48	+25
22	20	38	+18	25	39	+14
23	20	40	+20	25	35	+10
24	25	46	+21	21	36	+15
25	18	39	+21	18	37	+19
26	24	40	+16	19	38	+19
27	25	43	+18	25	39	+14
28	26	45	+19	18	40	+22
29	21	42	+21	19	37	+18
30	27	44	+17	18	39	+21
Mean	22.7	44.03	+21.33	21.03	41.00	+19.97

Table 2 shows that the mean student engagement score of urban students before exposure to Augmented Reality was 22.70, while that of their rural counterparts was 21.03. As presented in Table 2, after exposure to AR, the mean engagement score of urban students increased to 44.03, compared to 41.00 for rural students. A careful comparison of pre-intervention scores indicates that urban students had a slightly higher engagement level than their rural peers prior to the AR-based Mathematics instruction and after the intervention. To determine whether these observed differences in engagement scores—both before and after the intervention—were statistically significant or due to sampling variability, inferential statistical analysis was conducted.

Testing Null Hypotheses

Hypothesis One: There is no significant difference between the mean student engagement scores before and after the use of AR in Mathematics instruction.

Table 3: Paired sample t-test of Mean Student Engagement Scores Before and after the Use of AR

Variable	N	Mean	SD	Df	T	Sig
After	60	42.5166667				
			3.66292	59	-42.717	.000
Before	60	22.3166667				



As shown in Table 3, a t-value of -42.717 was obtained, with an associated probability (p-value) of .000. Since the p-value (.000) was less than the .05 level of significance established by the researchers, the null hypothesis was rejected. This result indicates that there was a statistically significant difference in student engagement scores before and after the implementation of AR in Mathematics instruction.

Hypothesis Two: There is no significant difference between the mean student engagement scores of urban and rural students before and after the use of AR in Mathematics instruction.

Table 4: Paired sample t-test of mean student engagement scores of urban and rural students before and after the use of AR

	Variable	N	Mean	SD	Df	t	Sig
Before	Urban	30	22.70	3.02	29	0.954	0.348
	Rural	30	21.93	2.84			
After	Urban	30	44.03	3.33	29	3.997	0.090
	Rural	30	41.00	3.25			

Furthermore, results presented in Table 4 indicate that the t-value for the difference between urban and rural students before exposure to AR was 0.954, with an associated p-value of .448. Additionally, a t-value of 3.997 with a p-value of .090 was recorded for the mean difference after exposure to AR. In both cases, the p-values were greater than 0.05, leading to the conclusion that the null hypothesis was not rejected. This implies that there was no statistically significant difference in the mean student engagement scores between urban and rural students, either before or after the AR intervention in Mathematics instruction.

Discussion

This study was conducted to investigate the effect of Augmented Reality (AR) on the engagement levels of low-achieving students in Mathematics within the Aba Education Zone. The findings of this study revealed a significant increase in student engagement scores after exposure to AR-based Mathematics instruction. The mean engagement score rose from 22.32 (pre-test) to 42.52 (post-test), indicating that AR had a strong positive influence on students’ interest, participation, and involvement in Mathematics learning. This outcome confirms the findings of Ibrahim and Park (2022) and Chen et al., (2023), who found that AR applications help students visualize abstract concepts, stay attentive, and experience reduced anxiety in Mathematics classrooms. Furthermore, the inferential analysis showed that the difference between pre- and post-test engagement scores was statistically significant, leading to the rejection of the null hypothesis. This supports Okoye and Lin’s (2021) assertion that AR tools enhance all three dimensions of engagement and improve overall classroom dynamics.



Interestingly, the study also found no significant difference in engagement between urban and rural students, both before and after exposure to AR. The finding highlights the important contributions of the study on AR technology as it can serve as an equalizing instructional tool that benefits students regardless of location or background. This aligns with the conclusions of Onwuka and Zhang (2023) and Umeh and Adeboye (2022), who noted that AR's flexibility—especially through mobile platforms—makes it adaptable for use in under-resourced rural schools as well as in more advanced urban environments.

Conclusion

The study concludes that Augmented Reality is a viable and effective tool for improving student engagement in Mathematics, especially for learners who have historically struggled with the subject. Its interactive and visual nature enables deeper conceptual understanding and sustained attention, which are essential for academic improvement.

Recommendation

Based on the findings of this study, the following recommendations are made:

1. Mathematics teachers should adopt AR as a standard teaching tool in Mathematics across all schools.
2. Both rural and urban schools should receive equitable access to AR tools, such as AR-enabled devices, learning software, and supporting infrastructure, to maintain the balance in engagement levels observed across zone.
3. Organize comprehensive training programs for Mathematics teachers in both rural and urban schools on the use of AR in teaching. This should include hands-on sessions to boost teachers' confidence and competence in technology-enhanced instruction.
4. The government should allocate funds specifically for the provision and maintenance of AR-compatible devices, internet access, and technical support in both rural and urban schools to ensure sustainability.

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