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Reducing Mathematics Anxiety through Smartphone-Assisted Jigsaw Cooperative Learning among Senior High School Students

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ABSTRACT

Mathematics anxiety continues to hinder students' performance and engagement, often resulting in poor learning outcomes. This study investigated the effect of a smartphone-assisted jigsaw cooperative learning strategy on the mathematics anxiety of senior high school students in Lagos State, Nigeria. Using a pretest-posttest quasi-experimental design with non-equivalent control groups, a total of 534 students were selected from two co-educational public schools. Instruments used included the Mathematics Anxiety Questionnaire (MAQ) and the Smartphone Efficacy Questionnaire (SEQ), with treatment delivered via the Roducate Educational App. Results revealed a reduction in mathematics anxiety among students exposed to the smartphone-assisted strategy compared to those taught using traditional methods. Although the decline was not statistically significant, trends showed the strategy favored male students and those with low smartphone efficacy. The findings suggest that technology-enhanced cooperative learning can support anxiety reduction and educational equity. Further research is recommended to explore long-term and broader impacts.

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1. INTRODUCTION

Mathematics anxiety refers to a feeling of fear and tension when faced with mathematical problems. It can also be described as a state of discomfort caused by performing mathematical tasks. Some researchers (Mammarella *et al.,* 2023) described mathematical anxiety as a feeling of unease and heightened physiological reactivity when people engage with mathematics. Mathematics anxiety has been found by scholars (Awofala & Esealuka, 2021; Awofala, 2019; Awofala, 2020; Awofala *et al.,* 2017; Awofala & Lawal,2019; Awofala & Akinoso, 2017; Awofala & Odogwu, 2017; Sopekan & Awofala, 2019) to interfere with the manipulation of numbers and the solving of mathematical problems thereby directly and indirectly influencing students' achievement or performance in mathematics.

Studies have considered mathematics anxiety to be one of the many factors responsible for students' poor performance in mathematics (Awofala & Ogunsanya, 2025; Adebiyi *et al.,*2024; Awofala *et al.,* 2024; Awofala & Akinoso, 2017; Awofala & Odogwu, 2017; Salman *et al.,* 2012, Shaikh, 2013; Udonsa, 2015; Salahot, 2022). Programme for International Student Assessment (PISA, 2019) found that a high percentage of secondary school students worry about mathematics and are in tension when doing mathematics homework (Commodari & La Rosa, 2021). Some researchers (Gunderson *et al.,* 2018) found mathematics anxiety to be a highly prevalent phenomenon among elementary school students. Other researchers (James *et al.,* 2013) found that a higher percentage of students had moderate mathematics anxiety. Some researchers (Beilock & Willingham, 2014) estimated that 25% of 4-year college students and up to 80% of community college students suffer from a moderate to high degree of mathematics anxiety. Furthermore, numerous studies (Awofala & Akinoso, 2017; Awofala & Odogwu, 2017; Awofala *et al.,* 2024; Richlan *et al.,* 2020; Mutegi et al, 2021) have found a negative relationship or correlation between mathematics anxiety and achievement or performance in mathematics. Some studies have found a significant relationship between mathematics anxiety, fear of COVID-19, depression from COVID-19, smartphone addiction, and nomophobia (Awofala *et al.,* 2025; Adebiyi *et al.,* 2024). Consequently, mathematics anxiety has been a topic of continuous research among scholars because of its predominance among students and its detrimental effect on students' mathematics performance or achievement.

In addition, studies (Toropova *et al.,* 2019; Zavareh *et al.,* 2022) have shown that students' mathematics anxiety can increase due to the choice of teaching method adopted by the teacher. Some researchers (Atoyebi & Atoyebi, 2022) also concluded that there exists a relationship between the teaching strategy used in mathematics classrooms and students' mathematics anxiety. However, in order to reduce students' mathematics anxiety, a menace that has persistently hampered students' ability to learn mathematics, teaching methods that encourage students' participation, collaboration, interaction, and problem solving in the learning process should be adopted (Kamran, 2023). One of such teaching methods is cooperative learning. Studies (Zavareh *et al.,* 2011; Moliner & Alegre, 2020) have identified cooperative learning strategy as a teaching strategy effective for reducing students' mathematics anxiety and improving students' achievement in the subject.

In today's information age, the growth of technology and its inclusion in the education system guide educators in the exploration of new teaching methods that can be used in the classroom as an alternative to teacher-directed techniques. More so, the increased availability of smartphones among senior secondary school students has become a concern to educational stakeholders who continually seek ways of making the teaching and learning environment interesting and adaptable to 21st-century learners who are technology-driven.

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Some researchers (Sung *et al.,* 2015) noted that integrating smartphones with effective teaching and learning strategies is necessary for improved learning achievement. In line with this, numerous studies (Ozer & Kilic, 2018; Fakomogbon & Bolaji, 2017; Each & Suppasetseree, 2021; Johnson & Lawal, 2022) have ascertained the effectiveness of the use of smartphones in a collaborative or cooperative learning environment on students' academic achievement and specifically mathematics achievement. However, there is a dearth of research on the effectiveness of the use of smartphones in a cooperative learning environment on students' mathematics anxiety.

Gender and smartphone efficacy are included in this study as moderator variables. Gender difference in mathematics anxiety is a continuous field of study since results have been inconclusive (Wang *et al.,* 2020). Some researchers (Hills *et al.,* 2016) found that girls exhibited higher mathematics anxiety at the primary and secondary levels of education. Some researchers (Van Mier *et al.,* 2018) found that boys and girls showed approximately equal levels of mathematics anxiety. Some researchers (Amam *et al.,* 2019) found no difference in the mean mathematics anxiety of students by gender. Some researchers (Asikhia, 2021) found a significant effect of gender on students' anxiety in mathematics. These contradicting findings further buttress the inclusion of gender as a moderator variable in this study.

The other variable moderating in the study is smartphone efficacy. Smartphone efficacy refers to the judgment of one's capability to use smartphones or the level of confidence a user has when confronted with the use of smartphones. Smartphone efficacy is included as a moderator variable because students must have a high level of confidence in using mobile technology as part of the teaching and learning process before the use of smartphones in teaching and learning can be successful (Mahat *et al.,* 2012). Students experience high self-efficacy in mobile learning, but no significant difference in male and female students' mobile efficacy (Yang, 2012). Studies on smartphone efficacy have been limited (Aminuddin *et al.,* 2021). As such, there is a dearth of research findings on the influence of smartphone efficacy on students' mathematics anxiety. This study, therefore, sought to investigate the effect of smartphone-assisted jigsaw cooperative learning on the mathematics anxiety of senior secondary school students in Lagos State, Nigeria. The influence of the moderating variables of gender and smartphone efficacy was also considered in the study.

The following research questions guided the study:

(i) What is the difference in the mathematical anxiety of senior high school students taught mathematics in a smartphone-assisted jigsaw cooperative learning environment and those taught in the traditional learning environment?
(ii) What is the influence of gender on students' mathematics anxiety?
(iii) What is the influence of smartphone efficacy on students' mathematics anxiety?
(iv) What is the effect of treatment and gender interaction on students' mathematics anxiety?
(v) What is the influence of the treatment on the mathematics anxiety of students with high and low smartphone efficacy?
(vi) What is the difference in the mathematical anxiety of male and female students with high and low smartphone efficacy?
(vii) What is the influence of treatment, gender, and smartphone efficacy interaction on students' mathematics anxiety?

The following null hypotheses were tested at a 5% level of significance:

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(i) There is no significant difference in the mathematics anxiety of students taught mathematics in a smartphone-assisted jigsaw cooperative learning environment and those taught in the traditional learning environment
(ii) There is no significant difference in the mathematics anxiety of male and female students
(iii) There is no significant difference in the mathematics anxiety scores of students with high and low smartphone efficacy.
(iv) There is no significant interaction effect of treatment and gender on students' mathematics anxiety.
(v) There is no significant influence of the treatment on mathematics anxiety of students with high and low smartphone efficacy.
(vi) There is no significant difference in the mathematical anxiety of male and female students with high and low smartphone efficacy.
(vii) There is no significant influence of treatment, gender, and smartphone efficacy interaction on students' mathematics anxiety.

2. METHODS

2.1. Research Design and Participants

Quasi-experimental research design of non –non-equivalent, pretest, posttest, and control group was used in the study. 534 second-year mathematics students from four intact classes of 2 senior high schools in Educational District IV of Lagos State, Nigeria, served as participants for the study. The schools were selected purposively based on the following criteria:

(i) School ownership (government)
(ii) Gender composition (co-educational)
(iii) Availability of smartphones to students (students of selected schools within the district provided with smartphones by the government)

The schools were assigned randomly to the experimental group (smartphone-assisted jigsaw) and the control group (traditional method) using a simple random sampling technique. The experimental group was taught using a smartphone-assisted jigsaw cooperative learning strategy while the control group was exposed to the traditional method of teaching for 8 weeks. Data were collected through the mathematics anxiety questionnaire (MAQ) and the smartphone efficacy questionnaire (SEQ), while smartphone smartphone-assisted learning package (SALP) served as the treatment instrument for the experimental group.

2.2 Instrument for Data Collection

Mathematics Anxiety Questionnaire (MAQ): The MAQ is a 15–item Likert-type instrument designed to measure students' mathematics anxiety. The instrument was adapted from the mathematics self-efficacy and anxiety questionnaire (MSEAQ). All statements of MAQ were taken and slightly adapted from the MSEAQ items 2, 3, 5, 6, 8, 11, 14, 15, 17, 18, 22, 24, 25, 26, and 27. The MAQ consists of 2 parts. Part A consists of the students' profiles: school, class, and gender of the student. Part B is made up of the adapted 15 items from the MSEAQ. Each item of the MAQ is rated on a 5-point modified Likert scale ranging from never = 1, seldom = 2, sometimes = 3, often = 4 to usually = 5.

Smartphone Efficacy Questionnaire (SEQ): The smartphone efficacy questionnaire (SEQ) is a 9-item Likert-type instrument designed to measure students' self-efficacy on mobile devices. The instrument was adopted from the 25-item questionnaire on "pupils' attitude and self-efficacy of using mobile devices" by rewriting the term "PDA" as "mobile device" (Nikolopoulou & Gialamas, 2017). The 9 items were adopted from items 17-25 of the "pupils' attitude & self-efficacy of using mobile devices" questionnaire. Each item of the SEQ is rated

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on a five-point Likert scale ranging from Strongly Disagree (1 point), Disagree (2 point), Undecided (3 point), Agree (4 point), to Strongly Agree (5 point). SALP or the Roducate Educational App was the treatment instrument used in the smartphone-assisted Jigsaw experimental group. The package contains subjects or topics that students encounter at the senior high school level. The main menu of the package consists of lectures, mock exams, tasks, and tutorial videos.

2.3 Procedure for Data Collection

Students who participated in the study were trained by an officer from the district on how to use the smartphone and, more importantly, how to make use of the Roducate App, which was used in the experimental group. The teacher and research assistant who participated in the study (especially in the treatment group) were trained in combining the SALP (the Roducate App) with Jigsaw cooperative learning. The treatment period for all groups covered 10 weeks. Students in the experimental group were heterogeneously divided into groups. At the beginning of the study, the MAQ and SEQ were administered to students in the sampled schools as pre-treatment questionnaires during the first week of the treatment to ascertain their level of mathematics anxiety before commencement of treatment. During the 8 weeks of the treatment, students in the experimental group were exposed to the use of smartphone-assisted cooperative learning as treatment, while students in the control group were exposed to the traditional teaching method. Immediately after the treatment, the MAQ was again administered as a post-treatment questionnaire.

2.4. Instructional procedure for the smartphone-assisted jigsaw

In its implementation, smartphone-assisted jigsaw cooperative learning applies the following 7 steps.

(i) Step 1: Students were divided into small heterogeneous groups called home groups, with 3 members in each group. Each member is then assigned a number/alphabet (say 1, 2, 3 or a, b, c) based on their ability level.
(ii) Step 2: The teacher introduces the topic for the lesson and states the objectives to be achieved by the end of the 80-minute lesson.
(iii) Step 3: Students are assigned a specific objective, or segment of the lesson, according to the number given to them in step 1.
(iv) Step 4: students assigned to the same objective or segment of the lesson come together to form an “expert group” where they learn and solve 1 or 2 exercises on the segment assigned (using the SALP/ Roducate App) while the teacher and research assistant move round to ensure that students are on track with what is being learnt and also ensure class decorum.
(v) Step 5: students return to their home groups and discuss/explain (using the lessons or videos on the SALP/ Roducate App as directed by the teacher) what is learnt in the “expert group” to the other members of their home groups in a bid to ensure that all members master the content of the lesson.
(vi) Step 6: Students as a group attempted the class exercise and submitted only one sheet after reaching a consensus.
(vii) Step 7: Students take individual tests at the end of a topic, which is marked by the teacher/research assistant.

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This also contributes towards the group, since groups where every member scored very well in the individual test are recognized and rewarded in class. Thereafter, the MAQ instrument was re-administered on the 10th week.

2.5. Traditional method

This strategy was characterized by the teacher solving all the theoretical or numerical problems on the board while the students learn by listening and copying the solved problems in their notebooks. There was minimal interaction between the teacher and the students.

2.6. Data Analysis

This strategy was characterized by the teacher solving all the theoretical or numerical problems on the board while the students learn by listening and copying the solved problems in their notebooks. There was minimal interaction between the teacher and the students.

3. RESULTS AND DISCUSSION

3.1. Research Question 1

What is the difference in the mathematical anxiety of senior high school students taught mathematics in a smartphone-assisted jigsaw cooperative learning environment and those taught in the traditional learning environment?. From **Table 1**, the mathematics anxiety mean score of students taught mathematics using smartphone-assisted jigsaw cooperative learning is 47.89 with a standard deviation of 11.64 after the treatment, as against their mean anxiety score of 51.43 with a standard deviation of 11.46 before the treatment. Also, students exposed to the traditional method had a mathematics anxiety mean score of 48.64 with a standard deviation of 11.86 after the treatment, as against their mean anxiety score of 48.26 with a standard deviation of 12.04 before the treatment. The mean difference of -3.54 and 0.38 for the two groups, respectively, indicates that students exposed to the smartphone-assisted jigsaw had a 6.89% decline in mathematics anxiety while their counterparts in the control group had an increase of 0.79% in mathematics anxiety mean score.

Table 1. Descriptive statistics of mathematics anxiety scores of students in the treatment group.

Treatment	N	Pre-treatment		Post-treatment		Mean diff.	% gain or loss
		Mean	SD	Mean	SD		
Smartphone-assisted jigsaw	256	51.43	11.46	47.89	11.64	-3.54	6.89
Traditional	278	48.26	12.04	48.64	11.86	0.38	0.79
Total	534	49.78	11.86	48.28	11.75		

3.2. Research Question 2

What is the difference in the mathematics anxiety score of students with high and low smartphone efficacy?. **Table 2** revealed that male students had a decline in mean anxiety score from 50.64 to 48.63, indicating a mean loss of 2.01, which represents 3.97%, while their female colleagues had a decline in mathematics anxiety from 48.24 to 47.64, indicating a mean loss of 0.60 (1.24%). This implies that male students had a greater decline in mathematics anxiety than their female counterparts.

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3.3. Research Question 3

What is the difference in the mathematics anxiety score of students with high and low smartphone efficacy?. **Table 3** indicates that students with high smartphone efficacy had a lower post-treatment mathematics anxiety mean score, showing a regression from a mean of 50.20 to 48.84 (mean difference -1.36) while their counterparts with low smartphone efficacy regressed from 49.10 to 47.39 (mean difference = -1.71). The above suggests that students with low smartphone efficacy had a higher decline in their mathematics anxiety (3.48%) while their colleagues with high smartphone efficacy had a mean anxiety loss of 2.71%.

Table 2. Descriptive statistics of the mathematics anxiety scores of male and female students.

Gender	N	Pre-treatment		Post-treatment		Mean diff.	% gain or loss
		Mean	SD	Mean	SD		
Male	343	50.64	11.96	48.63	11.72	-2.01	3.97
Female	191	48.24	11.56	47.64	11.81	-0.60	1.24

Table 3. Descriptive statistics of the mathematics anxiety scores of students with high and low smartphone efficacy.

Smartphone efficacy	N	Pre-treatment		Post-treatment		Mean diff.	% gain or loss
		Mean	SD	Mean	SD		
High	328	50.20	12.34	48.84	12.05	-1.36	2.71
Low	206	49.10	11.06	47.39	11.23	-1.71	3.48

3.4. Research Question 4

What is the effect of treatment and gender interaction on students' mathematics anxiety?. The interaction of treatment and gender under the smartphone-assisted jigsaw group, as presented in **Table 4**, resulted in a mean anxiety loss of 4.01 among male students, signifying a 7.74% loss in mathematics anxiety, whereas female students in the same group declined by 1.05 (2.08%). In the control group, male students recorded a mean anxiety gain of 0.25 (0.51%), but their female counterparts featured a 0.56 (1.20%) gain in mean anxiety score. The smartphone-assisted jigsaw cooperative learning strategy resulted in a fall in students' mathematics anxiety, with male students having the greatest decline, followed by their female colleagues, while the traditional method increased mathematics anxiety mean score, with the female students having a higher percentage increase when compared with the male counterparts in the same group.

3.5. Research Question 5

What is the effect of the treatment on the mathematics anxiety of students with high and low smartphone efficacy?. From **Table 5**, students in the traditional group with low smartphone efficacy recorded a higher increase in mathematics anxiety mean score (from 47.20 to 47.81) of 1.29%, while their colleagues with high smartphone efficacy had a mathematics anxiety gain of 0.43%. Interestingly, the highest decline (9.12%) in mathematics anxiety mean score was recorded under the smartphone-assisted jigsaw cooperative learning group of students with low smartphone efficacy, and this is followed by their counterparts with high smartphone efficacy (6.25%). It appears that smartphone efficacy has a great effect on students' mathematics anxiety. However, the effect was positive in the smartphone-assisted jigsaw group while in the control group, it was negative.

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Table 4. Descriptive statistics of treatment and gender interaction on mathematics anxiety of students.

Treatment	Gender	N	Pre-treatment		Post-treatment		Mean diff.	% gain or loss
			Mean	SD	Mean	SD		
Smartphone-assisted jigsaw	Male	181	51.78	11.68	47.77	11.80	-4.01	7.74
	Female	75	50.57	11.94	48.19	11.32	-1.05	2.08
Traditional	Male	162	49.35	12.17	49.60	11.60	0.25	0.51
	Female	116	46.73	11.74	47.29	12.15	0.56	1.20

Table 5. Descriptive statistics of treatment and smartphone efficacy interaction on students' mathematics anxiety.

Treatment	Smartphone efficacy	N	Pre-treatment		Post-treatment		Mean diff.	% gain or loss
			Mean	SD	Mean	SD		
Smartphone-assisted jigsaw	High	166	51.36	11.87	48.15	12.10	-3.21	6.25
	Low	90	51.56	10.73	46.86	10.73	-4.70	9.12
Traditional	High	162	49.02	12.73	49.23	12.03	0.21	0.43
	Low	116	47.20	10.98	47.81	11.62	0.61	1.29

3.6. Research Question 6

What is the difference in the mathematical anxiety of male and female students with high and low smartphone efficacy?. As presented in **Table 6**, the interaction of gender and smartphone efficacy shows that male students with low smartphone efficacy had a marginal loss of 2.99, signifying a 5.89% loss in students' mathematics anxiety, while their counterpart with high smartphone efficacy had a marginal loss of 1.44 indicating 2.85% loss in mathematics anxiety. Also, female students with high smartphone efficacy had a decline in mathematics anxiety mean score from 49.45 to 48.23, indicating a percentage mean anxiety loss of 2.47. However, female students with low smartphone efficacy had a slight increase in their mathematics anxiety mean score from 46.59 to 46.85 (mean difference = 0.26, indicating an anxiety gain of 0.56%).

Table 6. Descriptive statistics of gender and smartphone efficacy interaction on students' mathematics anxiety.

Gender	Smartphone efficacy	N	Pre-treatment		Post-treatment		Mean diff.	% gain or loss
			Mean	SD	Mean	SD		
Male	High	218	50.58	12.33	49.14	11.87	-1.44	2.85
	Low	125	50.73	11.34	47.74	11.49	-2.99	5.89
Female	High	110	49.45	12.38	48.23	12.48	-1.22	2.47
	Low	81	46.59	10.19	46.85	10.86	0.26	0.56

3.7. Research Question 7

What is the influence of the three-way interaction effect on students' mathematics anxiety?. The three-way interaction effect of treatment, gender, and smartphone efficacy on students' mathematics anxiety is presented in **Table 7**. Analysis reveals that male students with low smartphone efficacy exposed to the smartphone-assisted jigsaw cooperative learning had the highest (11.14%) decline in mathematics anxiety. This is distantly followed by high-level smartphone efficacy males in the same group, with a percentage decline of 5.75%, and high-level smartphone efficacy females also in the same group, with a decline of 5.48%. On the contrary, students exposed to the traditional method had a slight increase in

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their mean mathematics anxiety, with low smartphone efficacy females having the highest mean anxiety gain. The result of the analysis of the research hypotheses is shown in **Table 8** below.

Table 7. Descriptive statistics of the three-way interaction of treatment, gender, and smartphone efficacy interaction on students' mathematics anxiety.

Treatment	Gender	Phone efficacy	N	Pre-treatment		Post-treatment		Mean diff.	% gain or loss
				Mean	SD	Mean	SD		
Smartphone-assisted jigsaw	Male	High	115	51.15	12.06	48.21	12.15	-2.94	5.74
		Low	66	52.89	11.01	47.00	11.21	-5.89	11.14
	Female	High	51	51.84	11.55	49.00	12.09	-2.84	5.48
		Low	24	47.88	9.14	46.46	9.51	-1.42	2.97
Traditional	Male	High	103	49.95	12.66	50.18	11.47	0.23	0.46
		Low	59	48.31	11.30	48.58	11.83	0.27	0.56
	Female	High	59	47.39	12.79	47.56	12.87	0.17	0.36
		Low	57	46.05	10.62	47.02	11.45	0.97	2.11

3.8. Hypothesis one

There is no significant difference in the mathematics anxiety of students taught mathematics in a smartphone-assisted jigsaw cooperative learning environment and those taught in the traditional learning environment. **Table 8** shows the calculated value of F (1,525) for the effect of smartphone-assisted jigsaw cooperative learning anxiety on senior secondary school students had an associated probability ratio of 0.272. Since the probability value of 0.272 is greater than the 0.05 level of significance, the null hypothesis is accepted. This implies that there is no significant difference in the mean score of the students' mathematics anxiety when exposed to smartphone-assisted jigsaw cooperative learning and when exposed to the traditional learning environment.

Table 8. Result of ANCOVA on the effect of treatment, gender, and smartphone efficacy on students' mathematics anxiety.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3203.249[a]	8	400.406	2.987	.003	.044
Intercept	41983.419	1	41983.419	313.157	.000	.374
COVARIATE	2488.200	1	2488.200	18.560	.000	.034
TREATMENT	162.162	1	162.162	1.210	.272	.002
GENDER	34.110	1	34.110	.254	.614	.000
PHONEEFFICACY	166.180	1	166.180	1.240	.266	.002
TREATMENT * GENDER	128.928	1	128.928	.962	.327	.002
TREATMENT * PHONEEFFICACY	20.730	1	20.730	.155	.694	.000
GENDER * PHONEEFFICACY	3.675	1	3.675	.027	.869	.000
TREATMENT * GENDER * PHONEEFFICACY	11.236	1	11.236	.084	.772	.000
Error	70384.176	525	134.065			
Total	1318269.00	534				
Corrected Total	73587.425	533				

a. R Squared = .044 (Adjusted R Squared = .029)

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3.9. Hypothesis two

There is no significant difference in the mathematics anxiety of male and female students. ANCOVA analysis as presented in **Table 8** specifies the effect of gender on mathematics anxiety as F (1,525) = 0.254, p = 0.614, which is statistically insignificant at 0.05. This implies that gender does not bring about a significant difference in students' mathematics anxiety. Therefore, the null hypothesis, which says there is no significant difference in the mathematics anxiety scores of male and female students, was accepted.

3.10. Hypothesis three

There is no significant difference in the mathematics anxiety scores of students with high and low smartphone efficacy. **Table 8** revealed F (1,525) = 1.240, p = 0.266 > 0.05 as the effect of smartphone efficacy on senior secondary school students' mathematics anxiety. This implies that smartphone efficacy does not account for a significant effect on mathematics anxiety. Therefore, the null hypothesis that there is no significant difference in the mathematics anxiety score of students with high and low smartphone efficacy was accepted.

3.11. Hypothesis four

There is no significant interaction effect of treatment and gender on students' mathematics anxiety. On the interaction of treatment and gender on the mathematics anxiety of students, **Table 8** revealed that F (1,525) = 0.962, p = 0.327, which is not significant since p > 0.05. This is an expression of the fact that the treatment practically had the same effect whether a student was male or female, thereby eradicating gender influence.

3.12. Hypothesis five

There is no significant influence of the treatment on mathematics anxiety of students with high and low smartphone efficacy. ANCOVA analysis of treatment and smartphone efficacy interaction in **Table 8** showed that F (1,525) = 0.155, p = 0.694. With p > 0.05, students' mathematics anxiety did not respond to the treatment based on students' smartphone efficacy, whether high or low. The treatment, therefore, does not favour students with high smartphone efficacy differently from their counterparts with low smartphone efficacy. Partial eta squared expressly specified zero effect for the influence of the treatment on the mathematics anxiety of students with high and low smartphone efficacy. Thus, the null hypothesis is accepted.

3.13. Hypothesis six

There is no significant difference in the mathematical anxiety of male and female students with high and low smartphone efficacy. ANCOVA analysis of gender and smartphone efficacy interaction in **Table 8** showed that F (1,525) = 0.027, p = 0.869. With p > 0.05, students' mathematics anxiety did not respond to the gender, either male or female, based on students' smartphone efficacy, whether high or low. The gender, therefore, does not discriminate between students with high smartphone efficacy differently from their counterparts with low smartphone efficacy. Partial eta squared expressly specified zero effect for the influence of gender on the mathematics anxiety of students with high and low smartphone efficacy. Thus, the null hypothesis is accepted.

3.14. Hypothesis seven

There is no significant influence of treatment, gender, and smartphone efficacy interaction on students' mathematics anxiety. ANCOVA analysis of gender and smartphone efficacy

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interaction in **Table 8** showed that F (1,525) = 0.084, p = 0.772. This result shows that there was no significant three-way interaction effect of treatment, gender, and smartphone efficacy on students' mathematics anxiety. This hypothesis is therefore not rejected. Thus, the non-significant interaction accounted for 0.00% of the variation in the students' mathematics anxiety. It was concluded that there was no significant interaction effect of treatment, gender, and smartphone efficacy on students' mathematics anxiety.

Findings from this study showed that students exposed to a smartphone-assisted jigsaw cooperative learning strategy had a greater decline in mathematics anxiety when compared with their counterparts exposed to the traditional method. However, the result of the analysis related to the hypothesis indicated that the decline in students' mathematics anxiety was not statistically significant. This result contradicts the other findings (Zavareh *et al.,* 2022; Moliner and Alegre, 2020), who found that the choice of teaching method adopted by the teacher influences students' mathematics anxiety. It further contradicts the other findings (Mehidizadeh *et al.,* 2013) on the effectiveness of cooperative learning strategies in reducing the level of academic anxiety among students. However, the cooperative learning strategy is effective in increasing students' learning outcomes in mathematics (Awofala & Lawal, 2021; Awofala & Lawal, 2019). The reduction in mathematics anxiety of the experimental group in this study could be a result of the inclusion of smartphones in the teaching and learning process.

In this study, male students were found to have a greater decline in mathematics anxiety than their female counterparts. This finding aligns with other reports (Hills *et al.,* 2016; Mutodi & Ngirande, 2014) who found that female students had a slightly higher mathematics anxiety mean score than male students, and contradicts the other findings (Perez-Fuentes *et al.,* 2020) who reported that girls exhibited less anxiety than boys. This also contradicts the results (Asikhia, 2021), who found that male students had higher mathematics anxiety scores than female students. Analysis of covariance further indicated no significant difference in the mathematics anxiety of male and female students taught mathematics using a smartphone-assisted jigsaw cooperative learning strategy and those in the control group. This finding aligns with other reports (Al-Shannaq & Leppavirta, 2020), which found no significant difference in the mathematics anxiety of male and female students. However, it contradicts other reports (Asikhia, 2021), which found a significant difference in the influence of gender on students' anxiety in mathematics.

Analysis of the smartphone efficacy revealed that students with high and low smartphone efficacy had a slight increase in mathematics anxiety, with students with high smartphone efficacy having a greater increase in mathematics anxiety. However, this difference in mathematics anxiety score of students with high and low phone efficacy was not statistically significant, but the variable accounted for 0.2% of the variation observed in students' mathematics anxiety. Analysis on the effect of treatment and gender on students' mathematics anxiety showed that male students exposed to the smartphone-assisted jigsaw cooperative learning strategy had the greatest decline in mathematics anxiety when compared with female counterparts in the same group and students exposed to the traditional method. However, further analysis showed that the influence of treatment and gender on mathematics anxiety was statistically nonsignificant.

Findings from this study also revealed that students with low phone-efficacy in the smartphone-assisted jigsaw cooperative learning strategy had the greatest decline in mathematics anxiety compared to their counterparts with high phone efficacy and students exposed to the traditional method (who had an increase in their mathematics anxiety).

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However, ANCOVA analysis indicated no significant influence of treatment and phone-efficacy on students' mathematics anxiety. More so, there was no significant interaction influence of gender and phone efficacy on students' mathematics anxiety. This means that the effect of the phone efficacy was not similar across genders and that the phone efficacy was not gender sensitive.

Furthermore, there was no significant interaction effect of treatment, gender, and phone efficacy on students' mathematics anxiety. The non-significant three-way interaction effect is at variance with previous studies (Awofala & Nneji, 2012; Awofala, Balogun & Olagunju, 2011; Awofala *et al.*, 2013) on mathematics learning outcome. The present result revealed that the treatment, gender, and phone efficacy did not mutually influence mathematics anxiety to produce a joint effect. The non-significant three-way interaction effect is explainable in that the interaction of two of the variables did not change at different levels of the third variable. Thus, the mathematics anxiety of students with different genders and different phone efficacy tended not to be sensitive to the instructional strategies employed with regard to whether the students are male or female or whether they exhibit high or low smartphone efficacy.

4. CONCLUSION

This study on the effect of smartphone-assisted jigsaw cooperative learning strategy on the mathematics anxiety of senior high school students is worthwhile as it revealed that exposing students to the smartphone-assisted jigsaw cooperative learning strategy resulted in a decline in their mathematics anxiety, though the difference (decline) was not statistically significant. Specifically, the study showed that smartphone-assisted jigsaw cooperative learning strategy favoured male students better in that they had a greater decline in their mathematics anxiety when compared with their female counterparts (this difference was also statistically non-significant). Furthermore, smartphone-assisted jigsaw cooperative learning strategy narrowed the gap in mathematics anxiety between the better-privileged students (students with high phone-efficacy) and their less privileged colleagues (students with low phone efficacy), as partial eta squared specified zero predictive effect of the treatment on the mathematics anxiety of students with high and low phone-efficacy. Based on the findings of this study, the following recommendations are offered:

(i) Teachers should expose mathematics students to a smartphone-assisted jigsaw cooperative learning strategy as it will result in a decline in mathematics anxiety, which is one of the factors influencing students' performance in mathematics.
(ii) Government and non-governmental stakeholders should support students and teachers through the provision of smartphones to enhance the smartphone-assisted learning strategy.
(iii) A more comprehensive study on the effect of smartphone-assisted jigsaw cooperative learning strategy should be carried out to either buttress or negate the findings of this study.
(iv) Smartphone-assisted jigsaw cooperative learning strategy as a new paradigm in teaching and learning should be further explored for its effect on other learning outcomes.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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