Journal of Instructional Mathematics
E-ISSN 2722-2179
DOI: 10.37640/jim.v5i2.2188
Volume 5, Issue 2; 2024

Effects of Scaffolding and Conventional Instructional Methods on Female Students' Academic Achievement and Mathematics Anxiety in Geometry

Manko Umar Ahmad[1]*, Aliyu Alhaji Zakariyya[2], Alhassan D. Isa[1], Abubakar Sadiq Ndagara[1]
[1]Department of Mathematics, Niger State College of Education, Nigeria
[2]Department of Science Education, Ibrahim Badamasi Babangida University, Nigeria
*yamanalkali@gmail.com

Article Info

Received
November 27, 2024

Revised
January 3, 2025

Accepted
February 4, 2025

Keywords

Anxiety;
Conventional;
Geometry;
Mathematics;
Scaffolding.

Abstract

This study aimed to assess the effect of scaffolding and conventional instructional methods on female students' academic achievement and mathematics anxiety in geometry. The study used a quasi-experimental pre-test and post-test control design. The population comprised 443 SSII female students from 8 public schools in Agaie, Niger State, Nigeria. A sample of 130 SSII students from two schools was selected through multistage sampling. Data were collected through four instruments: Scaffolding lesson model for the experimental group, Conventional lesson model for the control group, Geometry Achievement Test (GAT) and Mathematics Anxiety Questionnaire (MAQ). The instruments were validated by three experts from two University. The reliability index of GAT and MAQ are 0.76 and 0.86 respectively. Research questions were answered through mean (M), standard deviation (SD), and mean difference, while a *t*-test at 0.05 level of significance was used to analyze the null hypotheses. The findings revealed that female students exposed to the scaffolding instruction method have higher mean scores than those exposed to the conventional instructional method. Based on the results, it is recommended, among others, that teaching mathematics, especially geometry, incorporate scaffolding instruction. Similarly, this method should be incorporated into the methodology and micro-teaching courses of pre-service teachers.

How to Cite:
Ahmad, M. U., Zakariyya, A. A., Isa, A. D., & Ndagara, A. S. (2024). Effects of Scaffolding and Conventional Instructional Methods on Female Students' Academic Achievement and Mathematics Anxiety in Geometry. *Journal of Instructional Mathematics, 5*(2), 136-145.

INTRODUCTION

The importance of mathematics cannot be denied in the growth and development of science and technology of any nation. Mathematics knowledge and competency proved to be vital vehicles for training the minds of students to think logically, objectively, and reasonably in solving daily problems. Mathematics, as a science subject taught at the post-primary level in Nigeria, is divided into seven segments:

number and numeration, algebra, mensuration, geometry, trigonometry, statistics, and probability (Zakariyya & Ahmad, 2021).

Geometry is a concept of mathematics which deals with the study of different shapes, either plane or solid shape. It is a vital area of mathematics which forms the building block of engineering and technical graphics. Geometry enables learners to know the facts and principles of science and its application. However, many learners have not been demonstrating strong conceptual knowledge of the concept. Many students in secondary schools were not adequately prepared for the geometry concept (Ahmad, 2016). Similarly, some previous research evidence has shown that students complained that some topics in mathematics are too difficult to understand and consequently cause mathematics anxiety and poor performance in the final examinations among students (Juman et al., 2022; Odor et al., 2024).

Such difficult topics, as observed by mathematics educators, include bearings, latitude and longitude, areas and volume of shapes, word problems and geometry constructions (Kwadwo & Asomani, 2021). These are attributed to some factors, which include instructional methods used by mathematics teachers in our schools, large class sizes, and inadequate learning materials for teaching the subject. Teachers of mathematics have been criticized for adopting conventional methods in teaching large classes with the intention of covering large content. The method is deficient in meeting the needs of the majority of students. It has also been described as a teacher centre and didactics with students simply listening, copying notes, doing homework and allowing easy handling of large classes without stress (Zakariyya & Ahmad, 2021). Thus, the method contains some demerits, among others, but it does not promote meaningful learning of mathematics as it appeals only to hearing. The conventional method is most often found to favour the educationally advantaged learners at the detriment of the educationally disadvantaged ones. This method has not been successful in promoting learners' anxiety in learning mathematics, which would enhance their high achievement in geometry (Zakariyya & Ahmad, 2021). Furthermore, the instructional method does not foster creative and logical thinking and collaborative problem-solving. Therefore, it has become very necessary to search for methods that ensure and enhance the academic achievement of students in mathematics, especially geometry concepts. For this reason, the researchers adopted scaffolding and conventional methods.

An instructional strategy where a teacher or a more knowledgeable peer assists a learner, called scaffolding, involves modifying the learning task so that the learner can solve problems or accomplish tasks that would otherwise be out of reach. It can also be regarded as a powerful instructional tool to help learners extend their level of understanding and complete tasks successfully (Yong, 2022). Ogundele (2020) see it as a teaching method in which learners are offered constructive support until when they can apply new skills and strategies individually. The scaffolding instructional strategy was based on the conceptual framework of Vygotsky's (1978) construct of the Zone of Proximal Development (ZPD). ZPD is the distance between the actual development level as determined by independent problem-solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers (Vygotsky, 1978).

It is an instructional method designed to promote a deeper level of learning. It is the support given during the learning process which is tailored to the needs of the students with the intention of assisting the learners achieved their learning objectives (Ahmad, 2016). The learners are well guided in the learning process, pushing them to think deeply and model the kinds of questions that they need to ask them, forming a cognitive apprenticeship. This method is not limited to the cognitive domain only, but it also relates to affective and emotive factors. During the process, the teacher might need to manage and control frustration, fear and loss of interest that the learners could experience. It encourages learners to take a more active role in the learning process by fully participating and engaging in problem-solving activities (Ahmad & Zakariyya, 2022).

Mathematics anxiety which can refer to the fear, tension, and apprehension individuals experience when facing mathematics problem is one of the psychological variables that has been found to have a negative influence on the performance and acquisition of mathematics skills (McCullagh et al., 2024). When mathematics anxiety becomes excessive, does not fit the situation, or lasts for a long time, it can interfere with students' performance on the task (Umar & Haruna, 2021). Studies of Barroso et al. (2021) and Caviola et al. (2022) have shown that mathematics anxiety is strongly related to mathematical performance. Mathematics anxiety affects student's confidence in the subject (Ahmad & Wachiko, 2021). Many learners of mathematics, especially geometry, suffer from mathematics anxiety and have little confidence in their ability to master the subject, and this, in turn, brings low performance in the subject (Yakubu et al., 2019). Psychologists view mathematics anxiety to be positive sometimes if it helps you deal with a tensed situation to study harder for exams, handle a new task, or stay focused on an important task.

On the other hand, gender differences in mathematics performance and the underrepresentation of females in mathematics and STEM (Science, Technology, Engineering, and Mathematics) disciplines have been well documented. According to the National Science Foundation (2018), women outnumber men in earning Bachelor's degrees in biological and agricultural sciences, psychology, and the social sciences. In the more mathematics-intensive areas of study, men outnumber women. Similarly, Campbell (2020) in her study of gender differences at the highest levels of mathematics achievement showed that the percentage of male students scoring in the top quartile (75th–89th, 90th–95th and 96th–100th percentiles) was greater than that of the female students. The result also revealed that the gap between the percentage of male and female students scoring in the top quartile grew wider in higher score bands. In most studies, male outperformed females in mathematics tests. For example, Oluyemo et al. (2020) study revealed that male students excel in mathematics more than their female counterparts. Efa and Frimpong (2023) study showed that there was a significant gender difference in students' performance in mathematics in favour of females.

Several studies examining gender differences in mathematics anxiety have found that females report higher levels of mathematics anxiety than male (Anbar et al., 2022; Delage et al., 2022; Hart & Ganley, 2019; Szczygiel, 2020). Several studies have also shown that instructional strategies that are student-centred and activity-based are effective in reducing gender differences in mathematics performance and anxiety. Allahnana et al. (2018) in their study have recommended

that teachers should make use of alternative teaching methods like the use of games and simulations to bridge gender gap in mathematics. Similarly, Nwoke et al. (2018) recommended that teachers should use innovative strategies in teaching mathematics to get both male and female students involved in classroom activities. Innovative strategies such as computer-assisted assessment model (Nasution et al., 2019), cooperative learning (Zavareh et al., 2022), and problem-based learning method (Ajai & Imoko, 2015) has been explored. This study, therefore, explores the effects of the scaffolding instructional method on female students' academic achievement and mathematics anxiety in geometry.

Objectives of the Study

The objectives of this research study are to: (1) Find out the effect of scaffolding and conventional instructional on the academic achievement of female students in geometry concepts of mathematics; (2) Examine the effect of scaffolding and conventional instructional methods on female students' mathematics-anxiety in geometry concepts of mathematics.

Research Questions

The following research questions were asked to guide the study: (RQ1) What is the significant difference in the academic achievement of female students exposed to scaffolding instructional method and conventional instructional method in geometry concepts in mathematics? (RQ2) What is the significant difference between the mathematics anxiety of female students exposed to the scaffolding instructional method and the conventional instructional method in geometry concepts in mathematics?

Null Hypotheses

The following null hypotheses were formulated and tested at alpha 0.05 level of significance: (H01) There is no significant difference in the academic achievement of female students exposed to the scaffolding instructional method and conventional instructional method in geometry concepts of mathematics, (H02) There is no significant difference in the mathematics anxiety of female students exposed to the scaffolding instructional method and conventional instructional method in geometry concepts of mathematics.

RESEARCH METHODS

The study adopted a quasi-experimental design with two groups: an experimental group and a control group. The experimental group was exposed to scaffolding instructional methods, and a lesson model was designed for the treatment. The steps involved in the use of the scaffolding instructional method are Introduction--Task Discussion--Collaborative learning--Apprenticeship--Evaluation.

The first step is Introduction, where the teacher assesses the learners' previous knowledge or mathematics skills through discussion or questioning. Next, in Task Discussion, the teacher introduces the new topic to spark students' interest and presents the task using the conventional instructional method. The process then moves to Collaborative Learning, where the teacher carefully groups the students and assigns them a task to achieve a common goal. After that, in the Apprenticeship

stage, students are given individual tasks to assess whether they have mastered the material. Finally, in Evaluation, the teacher evaluates students' understanding by assigning homework to be submitted in the next lesson.

This treatment lasts for 5 weeks. At the same time, the students in the control group were exposed to conventional instructional methods with different lesson models designed based on conventional methods.

The target population for the study consisted of all the 433 SSII female students in 8 public senior secondary schools of Agaie Local Government Area. The common nature of students that constituted the study is female by gender, age bracket of 16; the government-owned schools with similar socio-economic status, staffing, admission, promotion policies and adequacy of learning materials. The sample size comprised a total of one hundred and thirty (130) SSII students from two secondary schools, with 60 students in the experimental group and 70 students in the control group. The sample size of 130 was determined based on the central limit theory, which recommends an appropriate sample size of 30 students for research studies (Sambo, 2008). A systemic random sampling technique was employed to select the sample size. Details are provided in Table 1.

Table 1. Sample for the study

Name of School	Experimental	Control	Total
Gov't, Day Sec. Sch. Agaie	30	35	65
Gov't, Day Sec. Sch. E/Agaie	30	35	65
Total	60	70	130

GAT was generated through careful study of mathematics textbooks used in SSII classes in the selected schools. The items covered geometry topics and consisted of twenty multiple-choice questions with four options. MAQ consists of ten statements about geometry in mathematics. After each statement, the numbers (1, 2, 3, 4, and 5) are used to rate how true each of the following is of you: extremely or always true, not at all or never true. The statements in the inventory do not have right or wrong answers. The two instructionals were used for data collection and validated by three experts with the rank of senior lecturers, two from Ibrahim Badamasi Babangida University Lapai and one from Federal University of Technology Minna, respectively. The reliability coefficient of the instruments was achieved through Pearson product-moment correlation of the text retest of GAT and MAQ with a reliability index of 0.76 and 0.86, respectively. Data collected were analyzed using M, SD, mean difference, and *t*-test statistics at α=0.05 level of significance.

RESULTS AND DISCUSSION

Research questions are answered in each section regarding (1) female students' achievement in geometry: scaffolding vs conventional, and (2) female students' mathematics anxiety: scaffolding vs conventional.

Female Students' Achievement in Geometry: Scaffolding vs Conventional

In answering RQ1, descriptive statistics of M and SD was used and presented in Table 2.

Table 2. Descriptive Statistics of Experimental and Control Groups in GAT

Groups	N	M	SD	Mean Difference
Experimental	60	30.87	15.74	12.16
Control	70	18.71	13.02	

Results in Table 2 showed M and SD of academic achievement of female students in experimental and control groups. From the scores recorded, female students taught using the scaffolding instructional method had a M=30.87, and those taught using the conventional instructional method had a M=18.71. the large mean difference of 12.16 was recorded in favour of the experimental group.

About H01,—there is no significant difference in the academic achievement of female students exposed to the scaffolding instructional method and conventional instructional method in the geometry concepts of mathematics—to test this hypothesis, an independent sample *t*-test statistic was employed, and the result is provided in Table 3.

Table 3. The *t*-test Analysis of Experimental and Control Groups in GAT

Groups	N	M	SD	*df*	*t*-calc.	*p*-value	Remark
Experimental	60	30.87	15.74	128	2.01	0.000	Significant
Control	70	18.71	13.02				

GAT was administered to both groups to evaluate the effectiveness of the treatment. The result in Table 3 showed that o.05 is greater than *p*-value=0.000. Therefore, the stated null hypothesis was rejected. From this result, it is concluded that there was a significant difference in the achievement scores of the two groups that were taught geometry concepts of mathematics.

Female Students' Mathematics Anxiety: Scaffolding vs Conventional

In answering RQ2, descriptive statistics of M, SD, and mean differences were presented in Table 4.

Table 4. Descriptive statistics of Experiment and Control Groups in MAQ

Groups	N	M	SD	*df*	Mean Differences
Experimental	60	52.17	21.33	128	21.36
Control	70	30.81	10.31		

The result in Table 4 revealed that the mean score of the experimental group was M=52.17, while the control group was M=30.81. The large mean difference between the two groups was 21.36, which is in favour of the experimental group.

About H02,—there is no significant difference in the mathematics anxiety of female students exposed to scaffolding instructional method and conventional instructional in geometry concepts of mathematics—an independent sample *t*-test statistic tests the null hypothesis. The result was recorded in Table 5.

The result provided in Table 5 has proved that the scaffolding instructional method was significant in reducing mathematics anxiety since the alpha 0.05 level of significance is greater than the *p*-value=0.001. Therefore, the null hypothesis was rejected.

Table 5. The *t*-test Analysis of Experiment and Control groups in MAQ

Groups	N	M	SD	*df*	*t*-calc.	*p*-value	Remark
Experimental	60	52.17	21.33	128	4.02	0.001	Significant
Control	70	30.81	10.31				

Major Findings

The data collected were analyzed, and the following are major findings: (1) The first null hypothesis was rejected. Therefore, there was a significant difference between the academic achievement instructional method and the conventional instructional method in the geometry concepts of mathematics; (2) The second null hypothesis was rejected. Therefore, there was a significant difference in the mathematics anxiety of female students exposed to scaffolding instructional methods and conventional instructional methods in the geometry concepts of mathematics.

Discussion of the Findings

The result in Table 3 showed that 0.05 is greater than *p*-value=0.000. Therefore, the stated null hypothesis was rejected. As a result, it was concluded that there was a significant difference in the achievement scores of the two groups that were taught geometry concepts in mathematics. This shows that there was a significant difference between the experimental and control groups in GAT. The finding is in concurrence with that of Ahmad and Idrisu (2017) that students learn a task and perform heavily due to collaborative problem-solving, which allows them to participate actively in the conventional method. The scaffolding instructional method provides students with opportunities to learn mathematics, especially geometry, through social interaction; they perform heavily and retain more knowledge acquired.

The result provided in Table 5 has proved that the scaffolding instructional method was significant in reducing mathematics anxiety since the alpha 0.05 level of significance is greater than the *p*-value=0.001. Therefore, the null hypothesis was rejected. By implication, there was a significant difference between the experimental and control groups in terms of their mathematics anxiety towards geometry concepts of mathematics. This also confirmed the study of Ahmad (2016), Ahmad and Haruna (2021), that students involved in the scaffolding instructional method demonstrated successful performance and avoided unnecessary frustration due to social interaction between teacher-students and students-students. A low level of mathematics anxiety towards mathematics can result in higher performance in the subjectas stressed (Ahmad & Wachiko, 2021; Yakubu et al., 2019).

CONCLUSION

The first null hypothesis was rejected. Therefore, there was a significant difference between the academic achievement instructional method and the conventional instructional method in the geometry concepts of mathematics. The second null hypothesis was also rejected. Therefore, there was a significant difference in the mathematics anxiety of female students exposed to scaffolding instructional methods and conventional instructional methods in the geometry concepts of mathematics. Based on the findings, the scaffolding instructional method is an

effective method that can promote academic achievement and reduce mathematics anxiety towards geometry concepts in mathematics.

Based on the research findings, the following recommendations were made. First, mathematics teachers should be encouraged to teach geometry concepts using scaffolding instructional methods, as it has proven to be effective in improving academic achievement and mathematics anxiety. Second, it is good to provide adequate learning aids to support the adoption of the scaffolding method, as well as aids that can enhance the teaching and learning process, like geometry. Third, mathematics teachers should be exposed to scaffolding instructional methods through conferences, seminars, symposiums and in-service training. Fourth, students should be enlightened on vital vehicles in social interaction play in classroom situations, and they should also work with peers to assist in understanding the content and reduce mathematics anxiety because confidence is built through collaboration.

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