The Effect of the Experimentation Method on Students' Learning Achievement in Geometry: Evidence from Dar es Salaam, Tanzania

John Buzza*[1] & Septimi Kitta[2]
[1]National Institute of Transport, P. O. Box 705, Dar es Salaam, Tanzania
[2]Department of Educational Psychology and Curriculum Studies, School of Education, University of Dar es Salaam, Tanzania
Corresponding author*[1]: johnbuzza1970@gmail.com

Abstract

The problem of students' poor performance in Basic Mathematics cannot be solved without teachers' use of experimentation methods in teaching and learning Geometry. This present study evidenced that, the teaching and learning of Geometry is effective through experimentation methods. The study aimed to conduct teaching and learning experiments to compare the results of experimentation and non-experimentation methods in Tanzania. Using a quantitative approach grounded in positivist assumptions, quasi-experiments were conducted with experimental and control classes in four Ordinary Level secondary schools. Following a hypothesis, data collected through pretest and post-test were analysed using the paired and independent samples t-tests with the help of Cohen's d. The findings from a sample of 211 students revealed that the non-experimentation methods are not effective in learning Geometry. Besides helping to reach the schools, the probability sampling procedures enabled the arrangement of classes. The study recommends the use of experimentation methods in teaching and learning Geometry. As regards the limitations of the current study, further studies are also recommended.

Keywords: *active learning, transmission teaching, abstract concepts, traditional learning, students' performance*

DOI: *https://dx.doi.org/10.56279/ped.v42i2.special.4*

Introduction

Students' performance in compulsory Mathematics in secondary education is reported to be low worldwide. According to the Programme for International Students Assessment ([PISA], 2003), "students failed to demonstrate consistently that they had baseline Mathematical skills" (p. 91). Fourteen years later, PISA (2017) reported a low learners' performance in Mathematics worldwide especially in the schools where students had insufficient knowledge of Geometry. PISA (2017) highlighted that "the Mathematical performance can be seen in detail through problem-solving activity related to Geometry" (p. 10626). As PISA (2022) noted, students still face Mathematical challenges, which justifies a consistency in learners' poor performance worldwide. In addition to PISA's report, studies from different countries have reported consistently poor learners' Mathematical performance in secondary education. These include studies such as those in Malaysia (Abdullah & Zakaria, 2013), Cyprus (Panaoura, 2014), Tanzania (Kitta, 2015; Kyaruzi, 2023), Kenya (Ndinda, 2016), Namibia (Kanandjebo & Ngololo, 2017), Ghana (Rizki, Frentika, & Wijaya, 2018; Armal & Kissi, 2019), Iraq (Serin, 2018), Indonesia (Watan & Sugman, 2018), Turkey (Kandil & Bostan, 2019), the USA (Yi, Flores, & Wang, 2020), and Rwanda (Ntivuguruzwa & Mbarute, 2022).

Tanzania faces a critical challenge of poor student performance in Basic Mathematics at the ordinary level of secondary education. Mazana et al. (2020) reported that, on average, 82.5% of candidates failed Mathematics between 2008 and 2016. Similarly, records indicate that 80.9% of candidates failed the subject from 2014 to 2020 (MoEST, 2016; NECTA series, 2019–2020). Notably, the failure rate in Geometry is higher than in other Mathematics topics (NECTA series, 2014–2015, 2017–2019). This trend is concerning, as Geometry constitutes more than 60% of all Basic Mathematics topics (MoEST, 2017; MoEST, 2023). Despite the shift from a content-based to a competence-based curriculum in 2005 (Kitta, 2015; MoEST, 2017), many teachers continue to rely on the lecture method due to several challenges.

First, the syllabus remains overloaded, limiting the feasibility of activity-based learning (Paulo & Tilya, 2014). Second, large class sizes pose a significant challenge. While the government recommends a maximum of 40 students per class, many secondary school classrooms exceed this limit, accommodating more than 70 students (Mashala, 2019; Ndibalema, 2019; Godda, 2018; Siperto, 2018; HRW, 2017). For instance, a study by Siperto (2018) found that the average class size in O-level secondary schools in Buchosa District Council, Mwanza Region, was as high as 100 students. Large class sizes hinder effective classroom engagement and instructional strategies (Godda, 2018), making it hard for teachers to provide individualised support (HRW, 2017). Another major constraint is the severe shortage of Mathematics teachers (Human Rights Watch [HRW], 2017). For example, at one secondary school in Mwanza with 569 students enrolled in January 2016, only one out of 29 full-time teachers was a Mathematics teacher (HRW, 2017). This shortage often results in merged classes and increased teaching loads, limiting teachers' preparation time. Consequently, students' performance in Geometry remains consistently poorer than in other Mathema topics, as shown in Table 1.

According to PISA (2017), "Geometry is a fundamental branch of science in Mathematics and an essential component for developing mathematical thinking skills. Mathematical performance can be assessed in detail through problem-solving activities related to Geometry" (p. 10626). These statements suggest that Geometry serves as a foundation for understanding other areas of Mathematics, a notion that has also been recognised in Tanzania. In its Curriculum and Syllabus for Pre-primary Education, the Ministry of Education, Science and Technology [MoEST] (2023) states that "Early Numeracy Skills, such as identifying shapes, comparing and measuring objects, and analysing and arranging objects in a uniform order, help a child develop a broader understanding for making informed decisions" (p. 5). MoEST (2023) further states that these skills enhance a child's confidence and courage, which are crucial for academic progression and daily life. Similarly, in the USA, Yi et al. (2020) highlight that "familiarity with shapes, structures, locations, transformations, and proofs provides a foundation for understanding not only other areas of Mathematics but also subjects such as art, science, engineering, and social studies" (p. 1).

Despite the significance of Geometry, students in Tanzania perform worse in this area compared to other Mathematics topics, as reflected in Table 1. The data indicate that the lowest pass rate (0.7% in 2015) was recorded in Pythagoras' Theorem and Trigonometry, both of which are Geometry topics, whereas the highest pass rate (80.7% in 2014) was in Accounts, a non-geometry topic. Furthermore, other Geometry topics, such as perimeter, areas, and similarity, are among those with the lowest pass rates. Notably, all Geometry-related topics recorded a pass rate of 30% or lower, with most below 20%, except for Circles, Three-Dimensional Figures, and the Earth as a Sphere, which had a pass rate of 21.3% in 2019. Each year, NECTA conducts a topic-based analysis of students' performance in national examinations. Table 1 presents data for the years 2014–2020, during which the same set of topics was analysed. The table summarizes the percentage of candidates who passed each topic annually, offering insight into the persistent underperformance in Geometry.

Table 1

Analysis of Candidates' Performance Topic–wise in Basic Mathematics CSEE 2014-2015, 2017-2020

S/N	Topic/Subtopics	Percentage of Candidates who Passed						
		2014	2015	2017	2018	2019	2020	Average
1	Accounts	80.7	42.0	73.9	77.7	25.1	39.6	56.5
2	Statistics	47.9	29.9	56.8	50.1	53.4	50.3	48.1
3	**Linear Programming	35.4	53.6	07.0	34.7	25.6	16.5	28.8
4	Numbers, Fractions and Decimals	18.7	20.6	23.2	33.3	23.9	13.3	22.1
5	Rates and Variations	49.8	13.6	22.8	23.1	33.9	31.5	27.1

6	**Matrices and Transformations	29.6	16.5	25.6	20.3	22.7	21.6	22.7
7	Ratios, Profit and Loss	24.3	02.4	05.1	18.1	21.2	39.6	18.5
8	Sets and Algebra	35.2	07.8	19.0	17.3	18.5	8.2	17.7
9	*Pythagoras Theorem and Trigonometry	08.0	00.7	03.4	17.0	18.1	25.6	12.1
10	Sequences and Series	15.7	04.7	02.7	12.3	05.7	39.9	13.5
11	**Quadratic Equations	10.1	07.3	07.8	10.9	16.6	6.3	19.8
12	Exponents and Logarithms	14.5	12.3	15.3	10.2	12.8	14.4	13.3
13	**Functions and Probability	30.6	22.1	15.9	08.3	12.3	16.5	17.6
14	*Circles, Three Dimension Figures and Earth as a Sphere	09.3	12.9	08.3	07.5	21.3	8.6	11.3
15	*Vectors and Coordinate Geometry	14.8	06.1	14.6	05.3	15.9	17.1	12.3
16	*Perimeters, Areas, Congruence and Similarity	03.0	02.1	02.5	03.4	12.1	17.3	6.7

Source: NECTA series (2014-2015, 2017-2020)

* Geometry topics
**Topics which require prior knowledge of Geometry

Studies conducted on Geometry in other countries have emphasised the use of experimentation methods in teaching and learning Geometry. For example, in Malaysia, Abdullah and Zakaria (2013) noted that “Geometry learning should emphasise hands-on and mind-on approaches” (p. 252). This finding is similar to what was observed in Indonesia by Watan and Sugman (2018) who maintained that, “in Geometry, instructions are designed to explore problems by rotating, folding, measuring and drawing to obtain the implicit nature of concepts with teacher guidance” (p. 7). These findings emphasise experiments, which is learning by doing. Experiments such as paper folding can lead to a discovery of principles about angles and lines as confirmed by Ndinda (2016) in Kenya, and to a rise in learners’ performance in Geometry and other Mathematics as reported by Kurniati (2017) in Indonesia. Again, in Namibia, Kanandjebo and Ngololo (2017) suggested the use of ICT-driven pedagogy when teaching Geometry for students to grasp the concept of Geometry instead of memorising formulae. However, experimentation methods are not effectively practised in Tanzania (Paulo & Tilya, 2014; Kisakali & Kuznestov, 2015; HRW, 2017; Godda, 2018; Siperto, 2018; Mashala, 2019).

Furthermore, many of the studies conducted on Ordinary level secondary Mathematics in Tanzania are not focused on Geometry. For instance, Mazana et al. (2020) assessed students' performance in Mathematics while Kisakali and Kuznetsov (2015), Mabula (2015) and Michael (2015) observed factors leading to poor performance in Mathematics. Kitta (2015) contributed to specific projects whose aims involved improving teacher classroom practices. However, the studies conducted by Justini (2015) and Sichizya (1985) focused on Geometry. Justini (2015) was directed to primary schools and did a teaching experiment in Geometry with the control group learning through the lecture method while the experimental group was taught using the demonstration method. In this case, pupils were not allowed to participate in constructing Geometrical figures and doing the activities of locating and measuring angles and lengths as advocated by Panaoura (2014). This present study intended to achieve the practical work mentioned by Panaoura (2014) since it suggests the use of experimentation methods.

Although the study by Sichizya (1985) is somewhat old, it also failed to focus on teaching and learning methods. The study aimed to determine the extent to which factors such as the availability of Geometry equipment, school management, teacher experience, and both pupil and teacher attitudes toward Geometry influenced pupils' performance. It primarily compared the achievement of pupils in Geometry across schools with at least half of the required equipment (10 items listed in a checklist) and those with less than half of the equipment, without considering the teaching methods employed. Sichizya (1985) found that "the mean score for pupils in schools with at least half of the equipment was 6.59, while in schools with less than half, it was 3.56 out of 20 scores. When subjected to the t-test, the difference was statistically significant at the 0.1 level" (p. 64). Instead of focusing on experimental methods, Sichizya (1985) concentrated on factors that could affect the teaching and learning of Geometry. Consequently, the issue of teaching Geometry through non-experimental methods in Tanzania remains inadequately addressed.

As noted earlier by researchers from other countries, Geometry knowledge is crucial for representing and solving problems in other Basic Mathematics topics, and the teaching and learning of Geometry is most effective through experimental methods. This study suggests that there may be a missing link between the measures currently being taken and the root cause of learners' poor performance in Basic Mathematics in Tanzania. As Table 2 indicates, there is a persistent and significant failure rate in Basic Mathematics (averaging 80.9%), despite various interventions. Additionally, Table 1 further reveals that failure rates are disproportionately high in Geometry topics (averaging 91.36%) compared to other Basic Mathematics topics (averaging 75.22%). Although Geometry constitutes more than 60% of all Basic Mathematics topics in Tanzania, as outlined in the syllabus, little has been done to address the issue of excessive failure in this area. Studies conducted in

Tanzania have not focused on experimental methods, which have been shown in other countries to be more effective in teaching and learning. If the issue of students' failure in Geometry is not addressed, it will continue to adversely affect their overall performance in Basic Mathematics.

Table 2

Comparison between Pass and Fail Rates in Basic Mathematics

CSEE 2014 to 2020

Year	2014	2015	2016	2017	2018	2019	2020	Average
Pass	19.6	16.8	18.1	19.2	20.0	20.0	20.0	19.1
Fail	80.4	83.2	81.9	80.8	80.0	80.0	80.0	80.9

Source: MoEST (2016), NECTA (2019) & NECTA (2020)

Table 2 indicates that, on average, 80.9% of the candidates failed Basic Mathematics in the Certificate of Secondary Education Examinations (CSEE) each year despite measures being continually taken by the Tanzania government. The measures that are being taken by the government include the enhancement in teaching and learning environments, the change in classroom instruction methods, and teacher training programmes (Mazana et al., 2020)

To address the research problem, this study aimed to achieve the following specific objective:

To compare the performances of students exposed to experimental methods with those exposed to non-experimental methods in learning Geometry among ordinary-level secondary schools in Tanzania.

The corresponding hypothesis for this objective is as follows:

There is no significant difference in performance between students exposed to experimental methods and those exposed to non-experimental methods in learning Geometry.

Literature Review and Theoretical Framework

Literature review

Importance of mathematics

Mathematics plays a crucial role in everyday activities. For instance, a tailor requires mathematical skills to perform the necessary calculations when designing garments, while a mason relies on mathematics to lay bricks correctly. Similarly, carpenters, mechanics, plumbers, plate layers, and other craftsmen need a certain level of mathematical knowledge to succeed in their careers. As a result, various researchers emphasise that mathematical competencies are widely applied across many areas of human life (Mensah, Okyere, & Kuranchie, 2013; Tanveer, Rizwan, Ali, Arif, Saleem & Rizvi, 2013; Kisakali & Kuznetsov, 2015). These competencies are particularly important in scientific and technological development, as mathematical skills are essential for understanding other disciplines, including engineering, economics, business, natural sciences, social sciences, and even the arts (Tanveer et al., 2013). In this context, MoEVT (2014) reported that nearly every field of science in Tanzania relies on mathematical concepts, theories, and models. Mathematics is vital for understanding modern technology, and as noted by Kisakali and Kuznetsov (2015), it is taught at all levels of education in Tanzania, from pre-primary through Ordinary secondary education. Mathematics forms the foundation for both social and natural sciences through the development of principles, and it is widely applied in business, economics, engineering, and agriculture. Furthermore, it aids in logical reasoning and the organisation of proofs. However, despite its importance, there continues to be a significant failure rate in Basic Mathematics (Mazana, Montero & Casmir, 2020; MoEST, 2016; NECTA, 2019; NECTA, 2020).

Basic mathematics topics in Tanzania

According to MoEST (2017), Basic Mathematics in Tanzanian Ordinary-level secondary schools covers 38 topics, including numbers, fractions, decimals and percentages, units, approximations, and geometry. Other topics include algebra, ratios, profit and loss, coordinate geometry, perimeters and areas, exponents and radicals, quadratic equations, logarithms, congruence, similarity, geometrical transformations, the Pythagorean theorem, trigonometry, sets, statistics, relations, functions, rates and variations, sequences and series, circles, spheres, accounts, three-dimensional figures, probability, vectors, matrices and transformations, and linear programming. Of these, 14 topics are purely related to Geometry: perimeters and areas, coordinate geometry, congruence, similarity, geometrical transformations, the Pythagorean theorem, trigonometry, geometry, circles, spheres, and three-dimensional figures. These constitute 36.8% of all Basic Mathematics topics, more than one-third of the syllabus. While other topics such as relations, functions, vectors, matrices and transformations, linear programming, and quadratic equations are not exclusively Geometry, students cannot master them without prior knowledge of Geometry. In general, based on the Basic Mathematics syllabus (MoEST, 2017), Geometry covers more than 60% of all topics. This is also reflected in the new Basic Mathematics syllabus (MoEST, 2023), which focuses on competencies rather than specific topics. For instance, two of the three main competencies of the syllabus emphasise Geometry (MoEST, 2023:3), representing more than 60% of the content.

The place of learning methods in learners' performance

The importance of learning methods has long been receiving the consideration of many scholars worldwide. For instance, Tyler (1949), a classical American writer and Professor in the field of curriculum, highlighted that "although the particular learning experiences appropriate for attaining educational objectives will vary with the kind of objectives aimed at, teachers should have learnt certain principles that apply to the selection of learning experiences, whatever the objectives may be" (p. 65). Sixty-seven years later, Ifeoma (2016) in Nigeria argued similarly that "whatever learning outcomes students attain depend on what goes on in the classroom between teachers and students" (p. 82). The Nigerian national policy on education emphasises the importance of teachers, stating that "no education system can rise above the quality of its teachers" (Ifeoma, 2016, p. 82). Similarly, in Rwanda, Uwineza, Rubagiza, Hakizimana, and Uwamahoro (2018) argue that "students' performance in Mathematics depends on teachers' classroom gender-related practices" (p. 44).

The voice of educational researchers across the world is unanimous on the importance of learning methods. For instance, in Cyprus, Papanastasiou (2008) noted that teaching methodology has a direct effect on achievements in Mathematics and also on students' attitudes towards Mathematics, class climates and students' Mathematics self-perception. Papanastasiou (2008) discovered that the factor that accounts for the greatest differences related to Mathematics achievement between the more effective and less effective schools is transmission teaching, while the second factor is active learning. The other factors were successively mentioned as self-perception, student attitudes toward Mathematics, family incentives, and class climate. Therefore, based on such references like these, the prevailing study was conducted on learning methods. But it focused on comparing only experimentation and non-experimentation methods that are viewed by scholars in other countries that, participatory learning methods cause learners' high achievement in Geometry which leads to excellence in students' Mathematics performance (Abdullah & Zakaria, 2013; Panaoura, 2014; Seago et al., 2014; Tieng & Eu, 2014; Boakes, 2015; Ma et al., 2015; Ndinda, 2016; Kurniati, 2017 Watan & Sugman, 2018; Serin, 2018; Kandil & Bostan, 2019; Kumar et al., 2019; Kuzle & Gracin, 2019; Yi, Flores & Wang 2020). Furthermore, it has been provided that computer design systems promote experimental learning as students become involved in the discovery and construction of their knowledge (Das, 2019; Kumar & Kumaresan, 2020).

Theoretical framework

This study selected Van Hiele's theory of Geometric thinking which emphasises experimentation methods, and hence highlighting procedures recommended in other countries' literature about the teaching and learning of Geometry. Scholars such as Yi et al. (2020), Watan and Sugiman (2018), Ma, Lee, Lin and Wu (2015), and Abdullah and Zakaria (2013) have described Van Hiele's theory in five levels of learning: visual, descriptive, theoretical, formal logic, and rigour (the nature of logical laws).

At the first level, students learn Geometry through visualisation. They are provided with figures which are judged by their appearances. The current study aimed to improve this level by involving students in the construction of shapes as it was said by Panaoura (2013), a point that is not emphasised in Van Hiele's theory. At the second level figures are judged by their properties. A student may realise that the opposite sides of a rectangle are congruent. Students related figures and their properties in the third level. For instance, a student could understand why every square is a rectangle. At the fourth level, students could build deductive Geometric proofs because they understood the definitions and properties of figures. For example, students could prove why the diagonals of a rectangle are congruent. Lastly, at level five, students understand the way how mathematical systems are established. They can use all types of proofs and they can prove theorems. According to Tieng and Eu (2014:4), "to function successfully at a particular level, a learner must have acquired the strategies of the preceding level." The role of the teacher at every level is to provide students with necessary activities and guide the interactions using experimentation methods such as cooperative learning, discovery learning, Socratic Method, project-based learning and inquiry method.

Research Methodology

This study was guided by the assumptions in the positivist paradigm. The article presents findings from quasi-experiments that were conducted using quantitative methods. While the population of the study was all Ordinary level secondary schools in Tanzania, the target population consisted of only 14 schools (in the Dar es Salaam region) which appeared among the top ten schools and last ten schools in the country from the years 2016 to 2020.

Study area

In selecting a study area, Creswell (2018) advises researchers to consider the heterogeneity of the study population and to choose locations that reflect a range of variations in key characteristics. Dar es Salaam Region was purposively selected as it consistently contributed a significant number of schools to both the lowest – and highest-performing categories. Notably, in 2016, six of the ten lowest-performing schools were from Dar es Salaam (NECTA series, 2016–2020). Therefore, the study was conducted in the Dar es Salaam Region.

Sampling procedures

According to Alvi (2016), if the purpose of research is to draw conclusions or make predictions affecting the population as a whole, then probability sampling is appropriate. Probability sampling is a sampling procedure which uses statistical methods to select elements from a population. It is unbiased as it always facilitates valid conclusions about the population from which the sample was selected (Alvi, 2016). Thus, probability sampling was used to assign schools and participants to the control and experimental groups. In the first stage, stratified random sampling (which is a kind of probability sampling) was used in dividing the schools into two homogeneous subgroups. This is because the population had 14 Ordinary level secondary schools which were heterogeneous as regards performance; seven of them were among the ten best-performing schools in the years 2016 to 2020 while the rest belonged to the worst ten performing schools in that interval. According to Kombo and Tromp (2006), stratified random sampling is a method of selecting a sample that considers strata or the heterogeneous nature of a population by dividing it into homogeneous subgroups. A simple random sample is then taken in each subgroup in a way that proportionally represents the population.

Probability sampling was also used to get a sample of four schools (two schools from each subgroup); an experimental school and a control school were randomly selected from each category. The sample involved two experimental schools and two control schools. In each school, the Form Two class was purposively chosen, since the topic of similarity is in Form Two (MoEST, 2017). This is because Similarity was the leading Topic being poorly performed by candidates (NECTA series, 2014-2015, 2017-2020). One Form Two stream in each of the sampled schools was selected at random and its Mathematics teacher was purposively involved in the teaching and learning experiment. While the teachers who taught the experimental classes received a seminar before they started to teach, the ones who taught the control classes got the seminar at the end of the teaching and learning experiment for ethical considerations. This design collected quantitative data from 211 students (all the students in a stream were included). Thus, adding the four teachers, the sample comprised 215 participants. However, before the teaching and learning experiment could start, it was necessary to know whether or not the control and experimental schools in a subgroup were different or similar in terms of Geometry background knowledge. Therefore, a pre-test was applied which revealed that every pair of schools in each subgroup did not have a statistically significant difference in performance. The details are indicated in the findings and discussion section.

Training duration

The Basic Mathematics teachers who were involved in teaching both the control and experimental groups were oriented to exemplary curriculum materials in a three-day seminar at school H. This seminar was conducted by the researcher during which the mathematics teachers had an opportunity to contribute ideas for improving the exemplary materials. However, for ethical considerations, the teachers in the control schools received their training after data collection just to improve their teaching practices. During the training, teachers' activities in the experimental group included the preparation of figures/shapes, measuring angles and sides, constructing and drawing. In either phase, the timetable was the same. Day 1 was used in constructing diverse figures and discussing their properties and relationships, while Day 2 and Day 3 were devoted to deriving and proving Similarity theorems. Participants had enough time to discuss the applications of Similarity theorems in solving Mathematical and daily life problems. Regarding the teachers who attended the seminar, each possessed a diploma in Education and had teaching experience of more than 10 years in Mathematics.

Exemplary curriculum materials

This constituted activity-based lessons on the topic of similarity. The materials were designed following directives from the current Tanzanian Basic Mathematics syllabus for Ordinary secondary schools (MoEVT, 2017). Textbooks, supplementary books, and past papers were then selected according to the syllabus. However, the exemplary curriculum materials were prepared in such a way that students had the opportunity to do the activities by themselves under teacher guidance. The materials were prepared by the researcher in collaboration with experienced teachers who were acquainted with the teaching of Basic Mathematics in the context of a competence-based curriculum. The exemplary curriculum materials and the test with its marking scheme have been submitted separately from the manuscript.

Validity and reliability of research instruments

The probability sampling minimised threats of internal validities like the maturation, history and testing effects. Furthermore, the validation of instruments used in this study involved scrutinisation of the instruments by peer examiners. On the other hand, the instruments needed to be reliable by being qualified to give similar data when administered repeatedly (Taherdoost, 2016). Each of the instruments was applied to different groups during the teaching and learning experiments to measure the extent to which the groups consistently provided the same results.

Classroom intervention

The oriented teachers then used the exemplary curriculum materials for teaching the experimental groups. The control groups learnt Similarity through conventional methods as their teachers were not included in the seminar at the beginning. The teaching and learning experiment (in both the control and experimental groups) lasted for two weeks, which is the duration indicated in the syllabus for the coverage of the Similarity topic (MoEST, 2017). As the positivism paradigm insists on the privacy of participants to minimise bias (Park et al., 2019), the researcher was not involved in the teaching experiment.

Control of extraneous variables

The confounding or external variables were controlled in several ways which include the probability sampling of schools and participants, and using schools that were distant apart such that each school had only one class, experimental or control but not both. Other ways included the use of the same test and the hiding of hypotheses from participants.

Data analysis procedure

Paired samples t-test statistic was used to analyse the data gathered from the pretest and post-test. This is because the paired samples t-test is used to test if the means of two paired measurements, such as pretest/post-test scores, are significantly different (Warner, 2021). Comparison of means would lead to rejection or acceptance of the null hypotheses (Chittaranjan, 2019) and then enable explanations on whether or not two attributes (learners' scores in this case) are related.

Ethical considerations

This study received approval and permit from the University of Dar es Salaam, the District and Regional Authorities, and the heads of schools.

Findings and Discussion

This section presents the study's results, which are provided as answers to the hypothesis. With the help of SPSS statistical computations such as the Paired Samples t-test statistic, decisions were made concerning the rejection or acceptance of the null or alternative hypothesis.

Comparing the performance of students exposed to experimentation methods and students exposed to non-experimentation methods in learning geometry

The hypothesis of the study was, "Is there a significant difference in performance between students exposed to experimentation methods and students exposed to non-experimentation methods in learning Geometry?" The results are presented as follows:

Results of the pretest

The descriptive statistics of the pretest are shown in Table 3.

Table 3

Pretest Descriptive Statistics

	N	Minimum	Maximum	Mean	Std Deviation
Pretest school 1	51	12	56	46.37	11.278
Pretest school 2	41	17	58	45.29	6.882
Pretest school 3	62	0	16	4.83	4.910
Pretest school 4	57	1	7	4.34	3.487

Source: Field data 2022

The means in the high-performing schools (classes or groups) were 46.0 and 45.0. To discover whether or not the means were significantly different, the results were tested using the paired samples t-test statistic. The significant value was 0.1, which is above the 0.05 significance level. This indicates that the two means are not significantly different (Alnasraween, 2021; Chittaranjan, 2019). Thus, the difference in performance between the two high-performing classes was not significant statistically. In other words, the classes are equal in performance. Again, the means of the low-performing classes (schools) were 4.3 and 4.8. The paired samples t-test indicated a significant value of 0.48 which is greater than the 0.05 significant value. Therefore, the low-performing schools were also equal in performance.

Now, having observed in every pair that the schools were equal, one school in each pair was determined as an Experimental Group and the other one as a Control Group by use of random sampling techniques. That is, the two high-performing schools had now become a pair in which one was experimental group1 while the other was control group1; a change that applies similarly to the two low-performing schools for experimental group2 and control group2. The formation of groups gave room to the beginning of the teaching and learning experiment on the Topic of

Similarity, which lasted for two weeks according to the syllabus (MoEST, 2017). Thus 14 days after the pretest, the same test (now called posttest) was administered to experimental and control groups.

Results of the post-test

The descriptive statistics showing the means and standard deviations are displayed in Table 3.

Table 4

Post-test Descriptive Statistics

	N	Minimum	Maximum	Mean	Std Deviation
Post-test Experimental Group 1	51	76	98	85.92	6.099
Post-test Control Group 1	41	50	87	66.61	9.268
Post-test Experimental Group 2	62	7	85	46.82	19.208
Post-test Control Group 2	57	0	32	12.52	9.300

Source: Field data 2022

In either pair, the mean of the experimental group is higher than that of the control group. When the marks were subjected to the SPSS software, the results were as indicated in the paired samples t-test Table 5.

Table 5

Paired Samples T-Test Regarding Post-Test Results of Both Experimental Group 1 and Control Group 1

Pair 1:	Paired Differences					t	df	Significant Value (p-value)
Post-test Experimental Group 1 Post-test Control Group 1	Mean	Std Deviation	Std Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
	19.49	4.62	0.72	18.03	20.94	27.03	40	0.000

Source: Field data 2022

Regarding the experimental group 1 and control group 1, the means in the pretest results were 46 and 45 respectively, instead of 86 and 67 as it was in the post-test. This shows an improved performance in both groups, though the experimental class has gained more. Concerning the experimental and control groups, the size of the difference in their means is shown by the t-value of 27.03 as large enough to make the significant value 0.000 below 0.05. This indicates that the means are significantly different. Furthermore, Cohen's d which is calculated as (mean of experimental group-mean of a control group)/ (SD of the control group) = (86-

67)/9=19/9=2.1 indicates that the means differ by two standard deviations; implying a large effect (Verdugo, Garciab, & Tellez, 2015). Therefore, the difference in performance between the experimental group and the control group is significant statistically.

Again, the means of the experimental group 2 and control group 2 are 46.8 and 12.5 respectively. The pretest means were 4.3 and 4.8 respectively. Regarding the means, both the experimental and control groups have gained in performance, but there is a big difference between them which can be interpreted with the help of Table 5.

Table 5

Paired Samples t-Test Regarding Post-test Results of both Experimental Group 1 and Control Group 1

Pair 1: Posttest Experimental Group2-Posttest Control Group2	Paired Differences					t	df	Significant Value (p-value)
	Mean	Std Deviation	Std Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
	34.28	8.82	1.17	31.94	36.62	29.36	56	0.000

Source: Field data 2022

Table 5 refers to the significant value as 0,000 which is less than the 0.05 significance level. This shows a significant difference in the means. In addition, Cohen's d was calculated with reference to Table 3 as 3.6. This indicates a large effect (Bhandari, 2023). Therefore, the difference between the means is significant statistically. Therefore, the null hypothesis that, "there is no significant difference in performance between students exposed to experimentation methods and students exposed to non-experimentation methods in learning Geometry" is rejected; and the corresponding alternative hypothesis that, "there is a significant difference in performance between students exposed to experimentation methods and students exposed to non-experimentation methods in learning Geometry" is accepted.

There is a gain in performance by both pairs of the groups; the high-performing schools as well as the low-performing ones. Therefore, activity-based learning improves learning achievement in Geometry. There is also theoretical implication of the findings. Involving students before and during periods in doing experiments such as paper folding, constructing figures using materials in the local environment, and drawing and locating shapes, lines and angles on papers or with the help of computer algebra systems such as Mathematica and Maple improves learning as the underpinning theory suggests.

These findings also harmonise perfectly with several studies which were conducted earlier in other countries. For instance, Panaoura (2014:498) discovered that "the understanding of Geometry requires students to construct the appropriate figures to translate the verbal information and solve a Geometrical task." The same observation but in other words was later affirmed by Ndinda (2016) that experiments in paper folding can lead to the discovery of principles about angles and lines that facilitate understanding. These results also concur with the finding by Serin (2018) who contends that the teaching of Geometry is most effective through experimentation methods. Thus, in teaching Geometry topics, which consist of abstract concepts, there is a need for activities that will allow students to learn theoretical information by trying and proving using concrete materials in which learners are actively involved.

Conclusions

The findings of this study established that experimentation methods are the most effective in learning Geometry. The findings have provided clear evidence through repeated statistical tests in several teaching and learning experiments. It was confirmed that by using the traditional approaches (the non-experimentation methods), students' learning of Geometry in secondary schools will not be raised to the desired level. In light of this article, therefore, the study concludes that Geometry topics should receive special activity-oriented considerations involving experimentation methods should be used to teach and learn them. This is because it has been evidenced that Geometry comprises concepts which include more vocabularies than in the other areas of Basic Mathematics topics.

Recommendations

The recommendations are made in light of the study's findings, with a focus on policy considerations, teaching and learning practices, and avenues for further research.

The findings of this study highlight the necessity of using experimentation methods in teaching and learning Geometry to achieve desired outcomes in Basic Mathematics. It is recommended that schools be equipped with adequate classrooms, qualified teachers, and comprehensive teacher training to foster an environment conducive to implementing experimentation methods. The Basic Mathematics syllabus should also clearly differentiate between Geometry topics and other Basic Mathematics topics, as Geometry concepts are often too abstract for learners to grasp without active learning through experimentation methods. Additionally, the study recommends that Geometry topics be taught exclusively through experimentation methods. Special attention should be given to Geometry instruction, even in situations where teachers encounter challenges in adopting participatory methods. This is because non-experimentation methods are ineffective in teaching Geometry. It is also recommended that students be given opportunities to engage with concrete Geometrical materials during lessons and participate in constructing and preparing Geometrical figures before the lessons.

Given that this study compared experimentation and non-experimentation methods by analysing students' test scores in a limited sample of public and private Ordinary-level secondary schools in Tanzania, its scope was confined to one region and four schools. A more comprehensive study is recommended, involving a larger number of schools across the country for comparative analysis. Moreover, as this study employed only quantitative methods, future research should consider using mixed methods to capture a broader range of data and offer a deeper understanding of the issue, which quantitative methods alone cannot fully address.

References

Abdullah, A. H., & Zakaria, E. (2013). The effects of Van Hiele's phases of learning geometry on students' degree of acquisition of Van Hiele's levels. *Procedia-Social and Behavioral Sciences, 102* (13), 251-266.

Alnasraween, M. (2021). The statistical significance, practical significance and power of the statistical test. *Jordan Journal of Online Education, 20* (5), 5819-5831.

Amoo, S. A., & Disu, A. B. (2012). School environmental factors and mathematics teaching effectiveness: implication for e-learning. *Electronic Journal of Library Philosophy and Practice*, 8(3), 1-9.

Bailey, M. L., Taasoobshirazi, G., & Carr, M. (2014). A multivariate model of achievement in geometry. *The Journal of Educational Research, 107*(6), 440-461.

Bhandari, P. (2023). *What is effect size and why does it matter?* Scribbr.

Beard, C. (2018). *Experimental learning: a practical guide for training, coaching and education.* Kogan Page.

Boakes, N. J. (2009). Origami instruction in the middle school Mathematics classroom: Its impact on spatial visualisation and geometry knowledge of students. *Journal of Research in Middle Level Education, 32* (7), 1-12.

Cakmak, S., Isiksal, M., & Koc, Y. (2014). Investigating the effect of origami-based instruction on elementary students' spatial skills and perceptions. *The Journal of Educational Research, 107* (1), 59-68.

Chittaranjan, A. (2019). The p-value and statistical significance: misunderstandings, explanations, challenges, and alternatives. *Indian Journal of Psychological Medicine, 41* (3), 210-215.

Crawford, R., Jenkins, L., & Wan, L. (2023). 37 experimental learning projects as assessment in initial teacher education. *Australian Journal of Teacher Education, 48(*1), 36-47.

Creswell, W., & Creswell, J.D. (2018). *Research design*. SAGE Publications

Das, K. (2019). Role of ICT for better mathematics teaching. *International Journal of Education, 7(*4), 19-28.

Duru, A. (2010). The experimental teaching in some of the topics: Geometry. *Journal of Educational, Research and Review, 5*(10), 584-592.

Godda, H. (2018). Free secondary education and the changing roles of the heads of public schools in Tanzania: are they ready for new responsibilities? *Open Journal of Social Sciences, 10(6),* 1-23.

Human Rights Watch (HRW) (2017). *"I had a dream to finish school": barriers to secondary education in Tanzania*. https://www.hrw.org/report/2017.

Justini, P. (2015). *An investigation of teaching and learning geometry in mathematics at primary schools in Dar es Salaam, Tanzania [MA Dissertation]*. University of Dar es Salaam.

Kabote, S.J., Niboye E. P., & Nombo, C. I. (2014). Performance in mathematics and science subjects: a gender perspective for selected primary schools in rural and urban Tanzania. *International Journal of Gender and Women's Studies.* 2(3), 88-105.

Kanandjebo, L. N., & Ngololo, E. N. (2017). The effects of geometry sketchpad on grade 12 learners' performance in geometry. *International Electric Journal of Mathematics Education, 12* (3), 735-749.

Kandil, S., & Bostan, M. (2018). Effect of inquiry-based instruction enriched with origami activities on achievement and self-efficacy in geometry. *International Journal of Mathematical Education in Science and Technology, 50(4*), 557-576.

Kisakali, J., & Kuznestov, D. (2015). Modelling factors influencing mathematics learning and performance in Tanzanian secondary schools. *Asian Journal of Mathematics and Applications,* 1-11.

Kitta, S. (2015). Development of mathematics teachers: experience from Tanzania. *Int J EduSci, 8(1-ii*), 165-175.

Kumar, R. (2011). *Research methodology: a step-by-step guide for beginners* (3rd Ed.). Sage.

Kumar, R. S., Srinivas, S., Bose, A., Rahaman, J., Thakur, S., &Bapat, A. (2019). Examining knowledge demands for teaching class inclusion of quadrilaterals. *Group for the Psychology of Mathematics Education, 2(*43), 504-510.

Kuzle, A., & Gracin, D. G. (2019). Classroom social climate in the context of middle school geometry. *Group for the Psychology of Mathematics Education, 2* (43), 511-518.

Ma, H. L., Lee, D. C., Lin, S. H., & Wu, D. B. (2015). A study of Van Hiele's theory of geometric thinking among first through sixth graders. *Eurasia Journal of Mathematics, Science and Technology Education, 11*(5), 1181-1196.

Mabula, S. (2015). Modelling student performance in mathematics using binary logistic regression at selected secondary schools: a case study of Mtwara Municipality and Ilemela District. *Journal of Education and Practice,* 6(36), 96-103.

Mashala, Y.L. (2019). The impact of the implementation of free education policy on secondary education in Tanzania. *International Journal of Academic Multidisciplinary Research, 3(1),* 6-14.

Mazana, M. Y., Montero, C. S., & Casmir, R. O. (2020). Assessing students' performance in mathematics in Tanzania: the teachers' perspective. *International Electronic Journal of Mathematics Education, 15 (3), 1-28*

Mensah, J. K., Okyere, M., &Kuranchie, A. (2013). Student attitude towards mathematics and performance: Does the teacher's attitude matter? *Journal of Education and Practice, 4*(3), 132-139.

Mertens, D. M. (2012). *Research and evaluation in education and psychology: Integrating diversity with qualitative, and mixed methods*. SAGE Publications.

Michael, I. (2015). *Factors leading to poor performance in mathematics subject in Kibaha secondary schools [Master's dissertation]*. Open University of Tanzania.

MoEST. (2016). *Basic education statistics in Tanzania*. Author.

MoEST. (2017). *Basic mathematics syllabus for ordinary secondary education* (3rded.). Tanzania Institute of Education.

MoEVT. (2014). *Education and training policy.* Author.

MoEVT. (2019). *Education sector performance report, Tanzania mainland*. Author.

Moore, D. K. (2015). *Effective instructional strategies: from theory to practice*. SAGE Publications.

National Examinations Councils of Tanzania (NECTA). (2016). *Examination Statistics.* Author.

Ndibalema, P. (2019). Making sense of basic education statistics in Tanzania: emerging issues and implications for future practice. *International Journal of Elementary Education, 8(1),* 26-37.

Ndinda, M. D. (2016). An analysis of the factors influencing achievement in mathematics geometry among secondary school students in Makadara sub-county, Nairobi County [Master's dissertation]. Kenyatta University, Kenya.

NECTA series (2014-2015, 2017-2019). *Analysis of CSEE candidates' performance topic-wise.* Author.

NECTA series (2016-2020). *Form four results.* Author.

Ntivuguruzwa, C., & Mbarute, E. S. (2022). Factors affecting students' performance in mathematics in upper secondary schools in Gicumbi district, Rwanda. *Journal of Research Innovation and Implications in Education, 6*(3), 13-17.

Oco, R. M., & Sabasaje, S. N. (2023). Students' mathematical skills and knowledge. *International Journal of Multidisciplinary Research and Publications, 6*(2), 328-332.

Panaoura, A. (2014). Using representations in geometry: A model of student's cognitive and affective performance. *International Journal of Mathematical Education in Science and Technology, 45*(4), 498-511.

Papanastasiou, C. (2008). A residual analysis of effective schools and effective teaching in mathematics. *Studies in Educational Evaluation*, 34 (1), 24-30.

Park, Y. S., Konge, L., & Artino, A. R. (2019). The positivism paradigm of research. *Journal of Academic Medicine, 95*(5), 690-694.

PISA. (2017). Analysis of students' mathematics performance in solving the Programme for International Students' Assessment standard-based test item using a qualitative content analysis method. *Advanced Science Letters, 23* (12), 10625-10629.

PISA. (2003). *A profile of student performance in mathematics.* Retrieved from https://www.oecd.org.education.prog

PISA. (2022). *Mathematics assessment framework*. Retrieved from https://www.oecd.org.edu cation-prog.

Raja, F. V., & Najimonnisa, D. L. (2018). Comparing traditional teaching methods. *Journal of Education and Educational Development, 5*(2), 276-288.

Sakaran, U., & Bougie, R. (2012). *Research methods for business: a skill building approach*. Wiley & Sons Ltd.

Schiro, M. S. (2013). *Curriculum theory: Conflicting visions and enduring concerns.* New Delhi: SAGE.

Seago, N. M., Jacobs, J. K., Heck, D. J., Nelson, C. L., & Malzahn, K. A. (2014). Impacting teachers' understanding of geometric similarity: results from field testing of the learning and teaching geometry professional development. *Professional Development in Education, 40*(4), 627-653.

Seloraji, P., & Eu, L. K. (2017). Students' performance in geometrical reflection using GeoGebra. *Malaysian Online Journal of Educational Technology, 5* (1), 65-77.

Serin, H. (2018). Perspectives on the teaching of geometry: teaching and learning methods. *Journal of Education and Training, 5*(1), 131-137.

Sichizya, D. F. (1985). *Factors affecting achievement in geometry among form three secondary school pupils in Mbeya and Dar es Salaam regions [Master's dissertation]*. University of Dar es Salaam.

Singhal, R., & Kumar, R. (2015). Chi-square test and its application in hypothesis testing. *Journal of the Practice of Cardiovascular Sciences, 1(1), 69-71.*

Tanveer, M. A., Rizwan, M., Ali, N., Arif, M., Saleem, U., & Rizvi, S. (2013). Examining the role of attitude towards mathematics in students of management science. *Journal of Business and Management, 5* (3), 67-73.

Tellez, A., Garciab, C. H., & Verdugo (2015). Effect, confidence intervals and statistical powers in psychological research. *Psychology in Russia: State of the Art, 8(*3), 28-46.

Tieng, P. G., & Eu, L. K. (2014). Improving students' Van Hiele levels of geometric thinking using a geometer's sketchpad. *The Malaysian Online Journal of Educational Technology, 2* (3), 20-31.

Tulsian, P. C. (2010). *Business statistics: a self-study textbook.* S. Chand & Company Ltd.

Varaidzaimakondo, P., & Makondo, D. (2020). Causes of poor academic performance in mathematics at the ordinary level: a case of Mavuzani High School, Zimbabwe. *International Journal of Humanities and Social Science Invention, 9*(6), 10-18.

Warner, R. M. (2021). *Applied statistics I: basic bivariate techniques*. SAGE Publications.

Watan, S., & Sugiman (2018). Exploring the relationship between teachers' instructional and students' geometrical thinking levels based on Van Hiele's theory. *Journal of Physics: Conference Series, 1097* (1), 1-9.

Yi, M., Flores, R., & Wang, J. (2020). Examining the influence of Van Hiele theory-based instructional activities on elementary preservice teachers' geometry knowledge for teaching 2-D shapes. *Teaching and Teacher Education, 91*(2020), 1-12.

Yilmazer, Z., & Keklikci, H. (2015). The effects of teaching geometry on academic achievement by using the puppet method. *Procedia-Social and Behavioral Sciences, 191* (2015), 2355-2358.

Zimbardo, G. P., & Slavish, G. (2012). Transformational teaching: theoretical underpinnings, basic principles, and core methods. *Educational Psychology Review, 24 (*4), 569-608.