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PRE-SERVICE MATHEMATICS TEACHERS' KNOWLEDGE AND CONCEPTUAL UNDERSTANDING OF GEOMETRY IN NASARAWA STATE

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Abstract
This study ascertained pre-service Mathematics teachers' knowledge and conceptual understanding of Geometry in Nasarawa State. The study adopted causal-comparative research design based on action research paradigm. The population of this study was 155 pre-service Mathematics teachers in the Colleges of Education (Public & Private) in the Nasarawa State in 2022/2023 school year from the six Colleges of Education. The entire population of pre-service teachers were used for the study since it was not too large. The instrument used for this study was Geometry Conceptual Understanding Test (GCUT) developed in two phases by the researchers. The GCUT consisted of 40 items with options (A – D) and reasoning options (A – D) drawn across geometric concepts. It was content validated by specialists in mathematics education and science education. It was trial-tested on 123 pre-service mathematics teachers across mathematics combination from College of Education Akwanga. The internal consistency reliability coefficient of the instrument GCUT was computed using Kuder – Richardson ($K - R_{21}$) and the reliability coefficient of GCUT was found to be 0.81. The instrument was administered on the pre-service mathematics teachers to generate scores by experienced lecturers teaching the sampled students who served as research assistants. The data collected for the study were analysed using frequency counts and percentage were used to answer research questions 1 and 2 using a bench mark: below 40% - weak knowledge; 40 – 49% - moderately adequate knowledge and 50% and above – highly adequate knowledge. Descriptive statistics of mean and Standard Deviation were used to answer research questions three. Inferential statistics of t-test was used to test the hypothesis which involved comparing two means of groups. Findings revealed that pre-service mathematics teachers representing possess weak knowledge and conceptual understanding of geometry. There was also a significant difference between the pre-service teachers' knowledge in geometry and their conceptual understanding of geometry. Based on these findings, the researchers recommend among others that Colleges of Education authorities should ensure that qualified candidates who have evidence of competence in Mathematics and passion to study Mathematics are admitted to study pre-service Mathematics courses to prepare them for the tasks of guiding Basic Education students in geometry learning.

Key Words: Pre-service teachers, teachers' knowledge, conceptual understanding, geometry and Mathematics

Introduction

Mathematics is a science of structure, order and relationship that has evolved from practices and activities of humanity. Mathematics is an abstract science of numbers, quantities and space as in pure mathematics or as applied mathematics to other disciplines. Mathematics, being a central and core component in human activities, evolved from studying natural phenomena over time such as geometrical shapes, mensuration, trigonometry and day-to-day arithmetic (Zakariya, 2014). Mathematics is the science of structure which encompasses the use of symbolic logic, patterns and structure or constructs of the human mind and understanding. Hom (2018) defines Mathematics as the science that deals with symbolic logic and shapes, quantity and arrangement, space and mensuration. Mathematics is also seen as systematic communication of concepts (numbers, quantity, orders, and so on) and symbolic language of relationship used to describe how phenomena interact in real and applied situations (Petti, 2018). Mathematics is the science of pattern; pattern of counting, pattern of reasoning and communication, pattern of shapes, pattern of positions, pattern of changes and how these patterns are interwoven.

Mathematics is a core subject that involves several branches and geometry is one of such branches. Geometry is that branch of Mathematics that enables man to make predictions about the physical world and motivates man to study logic through observation and deductive proofs. Geometry is also a branch of Mathematics that deals with properties of arrangements of geometrical concepts like lines, circles and other shapes including their areas, dimensions and concerns properties of surrounding space and structure of configurations of these properties and their pressures on ecology of human existence (Porter, 2020**).**

Geometry is that branch of mathematics that deals with properties of configuration of geometrical objects starting with undefined concepts like points, then followed by concepts like straight lines and circles. Geometry existed independently of number and numeration in early cultures of humanity as practical ways for dealing with lengths, areas and volume of objects and this has influence on many fields such as Architecture, Physics and other branches of mathematics (Zuya & Kwalat, 2015). Hence, major components of Mathematics curriculum of geometry include the study of points, lines, angles, plane shapes, solid figures, as well as geometrical properties of congruence and similarity. The significance of these components of knowledge is the application in computer science and various branches of modern mathematics.

Geometry plays significant roles in life which offers mankind the thinking to reshape and modify the universe. Zuya and Kwalat (2015) opine that through the knowledge of geometry, mankind is able to describe, analyse and understand the world. To Heilbron (2018) Mathematics and other disciplines are related in variety of ways and opine that the theory of perspective in arts has geometric connotation in establishing visual-shape representations as well as the use of geometry in Architecture to define spatial forms of building in accordance with established principles of religion or aesthetic principles. This is to guarantee relevant buildings' decoration and proper design of buildings to meet environmental goals and minimize effect of wind speeds around bases of tall building structures. This means that, geometry has practical uses in almost all spheres of life. The concept of area has a huge influence in daily business. For instance, in planning construction projects, space is a significant issue of consideration, the concept of perimeter to integrate accurate materials like paints, fencing materials and so on, are geometric components of focus in

engineering fields (Bermanis, Salhov & Averbuch, 2021). Zuya and Kwalat (2015) state that learning and conceptual understanding of geometry develop ability in pre-service Mathematics teachers to do well in other areas of Mathematics which adversely instil in the students their understanding of the world in which they live. Knowledge of geometry is sine qua-non to learning and conceptual understanding of geometry and consequently paves for learning and understanding of Mathematics. The ability to solve problems in real life situations is hinged on sound knowledge of geometry, the teaching, learning and conceptual understanding of geometry should be handled by trained Mathematics educators (Onyeka & Charles-Ogan, 2018).

Knowledge of geometry is ability to describe ideas that consist of rules and procedures for solving mathematics problems that relate to geometric concepts. Possession of ideas and principles to deal with or accomplish tasks drawn from geometric contents and awareness of procedural orders to communicate such ideas to learners of mathematics constitute knowledge and understanding of geometry (Star & Stylianides, 2013). Geometry knowledge refers to knowledge of geometric concepts including principles and definitions of the geometric terms and concepts, procedures of action, sequencing and algorithms of the geometric contents used in problem solving involving geometry. Pre-service mathematics teachers' knowledge of mathematics contents and pedagogical knowledge are important for effective instruction in geometry teaching.

Conceptual understanding and knowledge operate together. Knowledge of geometry is knowing how to deal or solve geometric tasks by applying principles and definitions learnt on the concepts of geometry. Conceptual understanding of geometry is an outcome of knowledge from geometry without which certain contents or problems on geometry would be difficult to handle. Conceptual understanding of geometry, thus, gives pre-service mathematics teachers requisite experiences to deal with tasks on geometry relating to shapes, lines, angles, areas, and volumes. The global societies involve complex geometry components and conceptual understanding of these components should be built and impacted into individuals' cognition to give better vision of the world and enable individuals to solve problems relating to geometry (Malamed, 2015).

Pre-service teachers are students enrolled in an initial teacher preparation programme studying to become practicing teachers. Teachers' roles in classroom learning circumvent around knowledge of subject matter. Insufficient subject matter knowledge and conceptual understanding of the pre-service Mathematics teachers, who are teachers at Basic education levels, could lead to misinformation and misconception and this could impede students' interest, learning processes and performance in Mathematics. However, there is paucity of research on pre-service mathematics teachers' knowledge and conceptual understanding of geometry in the study area. It was against this backdrop that this study ascertained pre-service mathematics teachers' knowledge and conceptual understanding of geometry in Nasarawa State.

Statement of the Problem

The pre-service Mathematics teachers are trained to teach in Lower Basics and Upper basics of the school system, thus, should have adequate knowledge of geometry at Upper Basic II level. The pre-service Mathematics teachers' knowledge and conceptual

understanding of geometry are supposed to enable them to know the Upper Basic II geometric concepts. Low performance is noted in Basic Education Certificate Examination (BECE) in Mathematics as compared with other subjects. Mathematics group leader's reports (BECE, 2015- 2023) affirm that students' low grades in Mathematics were observed. This could be attributed to the Upper Basic students' weaknesses in geometric aspects of the Mathematics contents possibly occasioned by the Mathematics teachers' inability to cover geometric aspects of Mathematics curriculum as a result of their weaknesses in geometry. This is capable of hindering the production of future scientists, technologists, engineers and medical personnel that will contribute to national development. This scenario calls for research into the knowledge and conceptual understanding of geometry of pre-service Mathematics teachers and Upper basic II students who will teach geometry upon graduation. Therefore, the problem of this study was: what is pre-service mathematics teachers' knowledge and conceptual understanding of geometry in Nasarawa State?

Purpose of the Study

The main purpose of this study was to assess pre-service Mathematics teachers' knowledge and conceptual understanding of Geometry. In particular, the study:

1. Ascertained if pre-service Mathematics teachers possess adequate knowledge of geometry at Upper Basic II level.
2. Investigated pre-service Mathematics teachers' ability to demonstrate conceptual understanding of geometry by solving some geometric problems involving geometric shapes, angles and parallel angles.
3. Ascertained the difference in mean scores between pre-service Mathematics teachers' knowledge and their conceptual understanding of geometry?

Research Questions

The following research questions were raised to guide the study.

1. What percentage of pre-service Mathematics teachers possess adequate knowledge of geometry?
2. What percentage of pre-service Mathematics teachers demonstrate conceptual understanding of geometry associated with angles, parallel lines and other geometric concepts?
3. What is the difference in mean scores between pre-service Mathematics teachers' knowledge and their conceptual understanding of geometry?

Hypotheses

These hypotheses was formulated and tested at 0.05 level of significance.

There is no significant difference between the mean scores of pre-service Mathematics teachers' knowledge and conceptual understanding of geometry.

Research Method

This study adopted causal-comparative research design based on action research paradigm. The choice of this design was to identify cause-effect difference between groups of students so as to solve educational problems prevailing among pre-service mathematics teachers (Costello, 2023). The target population of this study was 155 pre-service Mathematics teachers in the Colleges of Education (Public & Private) in the Nasarawa State in 2022/2023 school year from the six Colleges of Education. The entire population of pre-service teachers were used for the study since it was not too large.

The instrument used for this study was Geometry Conceptual Understanding Test (GCUT) which is a two sections instrument, developed in two phases by the researchers. The first phase was the development of Geometry Knowledge Test (GKT) which formed first section of the GCUT solicited for knowledge of Geometry of the respondents. The development process of the GKT was

done to cover Geometric Concepts at the Level of Upper Basic II. The GKT which was open-ended type (short answers) test developed to solicit for pre-service mathematics teachers' responses on knowledge of geometric concepts, backing their answers with reasons, relating to definition of concepts and their properties. The responses of the pre-service mathematics teachers to GKT were used to develop the GCUT covering Geometry concepts.

The GCUT was an objective test instrument consisted of items of knowledge part options and conceptual understanding reasoning (R) part options developed by the researcher as Geometry Conceptual Understanding Test (GCUT). The GCUT constituted test items structured on geometric concepts to elicit the pre-service mathematics teachers' knowledge and conceptual understanding of geometry. The pre-service mathematics teachers' responses to GCUT's reasoning options were to demonstrate their conceptual understanding of geometric concepts after their responses on the knowledge part. The GCUT consisted of 40 items with options (A – D) and reasoning (R) options (A – D) drawn across geometric concepts. The instrument Geometry Conceptual Understanding Test (GCUT) was content validated by specialists in mathematics education and science education to enable the researcher go for trial test. The researcher gave the instruments to three experts in Mathematics Education and two experts in Science Education. The experts were requested to validate the 40-items test blue print developed by the researcher. The experts' views and suggestions were sought for in terms of content scope, content relevance, language level, vagueness and ambiguity for the geometrical concepts covered and the samples for the study. Based on their observations, questions 2, 26, 30 and 32 were restructured to conform with the study and the 40-items test were reduced to 30-items test following rejection of questions 6, 8, 14, 17, 20, 23, 25, 28, 35 and 40 by psychometric analysis of the test items. The experts' comments and advice were reviewed to come up with the final GCUT items that were used for this study

The developed instrument GCUT was trial-tested on 123 pre-service mathematics teachers across mathematics combination from College of Education Akwanga. The internal consistency reliability coefficient of the instrument GCUT was computed using Kuder – Richardson (K – R_{21}) and the reliability coefficient of GCUT was found to be 0.81. The instrument was administered on the pre-service mathematics teachers to generate scores which were used to analyse the study. Experienced Lecturers teaching the sampled students were used as research assistants. The researcher gave the research assistants orientation training on how to administer the instrument. The data collected for the study were analysed in line with answering research questions and testing the hypotheses formulated for the study. Descriptive approach using frequency counts and percentage were used to answer research questions 1 and 2 using a bench mark: below 40% - weak knowledge; 40 – 49% - moderately adequate knowledge and 50% and above – highly adequate knowledge. Descriptive statistics of mean and Standard Deviation were used to answer research questions 3. Inferential statistics of t-test was used to test the hypothesis which involved comparing two means of groups on the postulation that the data that were obtained are normally distributed (Iortimah & Aligba, 2017).

Results

Research Question One

What percentage of pre-service mathematics teachers possess adequate knowledge of geometry?

Table 1: *Frequency and Percentage of Pre-service Mathematics Teachers having Adequate Knowledge of Geometry*

Scores	Frequency	Percent	Cumulative Percent
3	2	1.3	1.3
4	2	1.3	2.6
5	7	4.5	7.1
6	8	5.2	12.3
7	12	7.7	20.0
8	40	25.8	45.8
9	22	14.2	60.0
10	14	9.0	69.0
11	19	12.3	81.3
12	7	4.5	85.8
13	5	3.2	89.0
14	6	3.9	92.9
15	2	1.3	94.2
16	4	2.6	96.8
17	2	1.3	98.1
21	1	0.6	98.7
22	1	0.6	99.4
24	1	0.6	100.0
Total	**155**	**100.0**	

Table 1 reveals that only 29 pre-service mathematics teachers scored 12 and above with percentage of 18.71%. This means 18.71% pre-service mathematics teachers possess knowledge of geometry. It can be seen that out of the twenty-nine (29) pre-service Mathematics teachers, eleven (11), 7.10% possess adequate knowledge of Geometry having scored 15 and above out of 30 marks. Eighteen (18), 11.61% possess moderate knowledge of Geometry at pass level, having scored 12, 13 and 14 marks out of 30 marks. One hundred and twenty-six (126); 81.29% pre-service mathematics teachers scored less than 12 marks out of 30. Thus, one hundred and twenty-six pre-service mathematics teachers representing possess weak knowledge of geometry.

Research Question Two

What percentage of pre-service mathematics teachers demonstrate conceptual understanding of geometry associated with angles, parallel lines and other geometric concepts?

Table 2: *Frequency and Percentage of Pre-service Mathematics Teachers with Reasoning Aspect of Conceptual Understanding of Geometry*

Scores	Frequency	Percent	Cumulative Percent
1	1	0.6	.6
3	2	1.3	1.9
4	7	4.5	6.5
5	18	11.6	18.1
6	12	7.7	25.8
7	11	7.1	32.9
8	40	25.8	58.7
9	21	13.5	72.3
10	9	5.8	78.1
11	8	5.2	83.2
12	5	3.2	86.5
13	12	7.7	94.2
14	4	2.6	96.8
15	1	0.6	97.4
19	1	0.6	98.1
22	1	0.6	98.7
23	2	1.3	100.0
Total	**155**	**100.0**	

Analysis of data from Table 2 revealed that twenty-six (26) pre-service mathematics teachers scored 12 and above, showing 16.77% of them who demonstrated their conceptual understanding of geometry based on responses to reasoning aspect of Geometry understanding test. Out of the twenty-six (26) pre-service teachers, five (5), 3.22% demonstrated adequate conceptual understanding at credit level, having scored 15 marks and above. Twenty-one (21), 13.55% justified moderate understanding of Geometry at pass level with scores 12, 13 and 14 out of 30 marks. One hundred and twenty-nine (129; 83.23%) of them could not demonstrate their conceptual understanding of geometry with scores below 12 marks showing weak conceptual understanding. Thus, for a student to have demonstrated or deemed to have conceptual understanding of geometry, the student should have scored both the options (and reasoning option also) correct. Data in Table 3 shows details of pre-service mathematics teachers who really

demonstrated their conceptual understanding of geometry by getting both options correct.

Table 3: *Frequency and Percentage of Pre-service Mathematics Teachers Who Demonstrated Conceptual Understanding of Geometry*

Scores	Frequency	Percent	Cumulative Percent
0	4	2.6	2.6
1	10	6.5	9.0
2	37	23.9	32.9
3	28	18.1	51.0
4	19	12.3	63.2
5	30	19.4	82.6
6	9	5.8	88.4
7	4	2.6	91.0
8	6	3.9	94.8
9	2	1.3	96.1
12	1	0.6	96.8
13	1	0.6	97.4
14	1	0.6	98.1
17	1	0.6	98.7
20	1	0.6	99.4
21	1	0.6	100.0
Total	**155**	**100.0**	

Table 3 reveals that only six (6; 3.87%) of pre-service Mathematics teachers demonstrated their conceptual understanding of geometry by getting 12 marks and above correct in both options of the GCUT. Out of the six (6) pre-service Mathematics teachers, three (3), 1.935% demonstrated adequate conceptual understanding of Geometry at credit and scored 15 marks and above and three (3), 1.935% demonstrated moderate conceptual understanding having scored 12, 13 and 14 marks. It can be seen from data in Tables 1 and 2 that pre-service mathematics teachers' scores on knowledge and conceptual understanding of geometry might have been obtained by guessing. This is because data in Table 3 revealed and showed that one hundred and forty-nine (149; 96.13%) of the pre-service mathematics teachers could not demonstrate their conceptual understanding of geometry and got between 0 and 12 on basic concepts and reasoning options correctly.

Research Question 3

What is the difference between pre-service mathematics teachers' knowledge and their conceptual understanding of geometry?

Table 4: *Mean and Standard Deviation of Scores of Pre-service Mathematics Teachers on Knowledge and Conceptual Understanding of Geometry*

Concept	**N**	$\bar{X}$	***SD***
Knowledge of Geometry	155	9.52	3.29
Conceptual Understanding of Geometry	155	9.61	3.46
Mean Difference		0.09	

Table 4 shows that the mean score of the pre-service mathematics teachers with knowledge of geometry is 9.52 with standard deviation of 3.29 while the mean score of the pre-service mathematics teachers in conceptual understanding of geometry is 9.61 with standard deviation of 3.46. The mean difference between the pre-service mathematics teachers' knowledge in geometry and conceptual understanding of geometry is 0.09 in favour of conceptual understanding of geometry.

Hypothesis

There is no significant difference between the mean scores of pre-service mathematics teachers' knowledge and conceptual understanding of geometry.

Table 5: *t-test Results of Pre-service Mathematics Teachers' Scores in Knowledge and Conceptual Understanding of Geometry*

Group	**No**	$\bar{X}$	**σ**	**df**	**t**	**p**	**Decision p<0.05**
Knowledge	155	9.52	3.29				
				308	2.37	0.018	S
Conceptual Understanding	155	9.61	3.46				

Note: NS – Not Significant @ p > 0.05; S – Significant @ p < 0.05

Table 5 shows t = 2.37 and p = 0.018, a summary of t-test to compare pre-service Mathematics teachers' knowledge in geometry and their conceptual understanding

of geometry. Since the significant value (p) is less than the set significant value for the test ($p < 0.05$), the hypothesis of no significant difference between the pre-service mathematics teachers' mean scores in knowledge of geometry and conceptual understanding of geometry under study was rejected. This means there is a significant difference between the pre-service teachers' knowledge in geometry and their conceptual understanding of geometry.

Discussion of Findings

Findings reveals that pre-service mathematics teachers possessed weak, limited and insufficient knowledge of geometry and this was seen in their inability to sufficiently score high marks on knowledge test. The pre-service mathematics teachers lack conceptual understanding of geometry and could not demonstrate any conceptual understanding of geometry through performing some tasks on geometry. Most of the scores they obtained in conceptual understanding test were at variance with that of the knowledge part. It was observed that there was a significant difference between the pre-service mathematics teachers' knowledge in geometry and their conceptual understanding of geometry. This finding agrees with that of Onwulji, Omenka and Akpan (2018); Ugwuanyi and Christopher (2018) who found that the pre-service mathematics teachers had weak conceptual knowledge because most of them managed to solve problems on knowledge of geometry but not on conceptual understanding of geometry. This implies that, the pre-service mathematics teachers' conceptual understanding of the geometric concepts was not sufficient, they have weak knowledge of geometry and lack conceptual understanding to justify their knowledge of geometric concepts.

The result of the analysis further shows that the hypothesis of no significant difference between the pre-service Mathematics teachers' mean scores in knowledge of geometry and conceptual understanding of geometry was rejected. The implication is that the pre-service mathematics teachers demonstrated competence in some areas of geometry and lack or have insufficient understanding in some concepts of geometry which resulted in scoring better in some areas of geometry and lower elsewhere. This finding is in agreement with findings of the studies conducted by Muhammad and Manko (2018); Omenka, Kyeleve and Tali (2018) that pre-service teachers could have difficulties in conceptualising some geometric concepts by being unable to solve problems on concepts of geometry and this could negatively affect students' performance.

Conclusion and Recommendations

Based on the findings of this study, the conclusions drawn were that pre-service mathematics teachers possessed weak, limited and insufficient knowledge of geometry and this was seen in their inability to sufficiently score high marks. Based on these findings, the researcher recommends that:

1. Colleges of education authorities should ensure that qualified candidates who have evidence of competence in Mathematics and passion to study Mathematics are admitted to study pre-service Mathematics courses to prepare them for the tasks of guiding Basic Education students in geometry learning.
2. State Basic Education Board should initiate workshop for the teachers to acquaint them with the principles of instructions to implement the geometric aspects of the Mathematics curriculum.

3. Mathematics teachers and lecturers should reduce their dominance in the teaching and learning of geometry, for that would reduce the students to passive listeners/learners.

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