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Availability of Manipulatives in Teaching and Learning of Mathematics in Colleges of Education in Ghana

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Abstract One of the many strategies by which students can bring meaning to abstract mathematical ideas is through the use of manipulatives. Manipulatives have the ability to help students learn new concepts and relate new concepts to what they have already learned. However, students' ability to use them depends on their availability in schools. This study therefore examine the availability of manipulatives in Colleges of Education in Northern Ghana. By doing so 291 pre-service teachers who were randomly selected were presented with checklist to complete, while 8 college staff were interviewed of which 2 were the Heads of the mathematics and ICT department. The results revealed that concrete non-geometry manipulatives were available to pre-service teachers than the concrete geometry manipulatives. Geogebra emerged as the common virtual manipulatives readily available to pre-service teachers. The results further indicated that even though some concrete manipulatives were available, they were inadequate to enhance pre-service teachers' learning of mathematics. In concluding, the paper suggests that pre-service teachers' knowledge in mathematics can be enhanced if efforts are made by school authorities and other stakeholders to acquire concrete manipulatives while students are encouraged to purchase virtual manipulatives on their own.

Keywords: *concrete manipulatives, virtual manipulatives, geometry, Teaching and Learning*

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1. Introduction

Many students in Sub-Sahara African countries are grappling with simple but innovative ways of learning mathematics. From the perspective of mathematics scholars, the subject can be learned from three broad angles; visual learning, auditory learning, and kinaesthetic learning. All these categories of learning cannot do away with manipulatives in learning mathematics especially geometry, which deals with points, lines shapes, and spatial objects. With the effective use of manipulatives in teaching mathematics, the teacher can communicate with each of these groups. As a result, all these groups can benefit from the lesson. However, one of the prevailing factors preventing teachers from using manipulatives to teach mathematics is the non-availability of the manipulatives [1,2] The literature further indicates that even teachers who use the manipulatives only resort to the demonstration method of teaching to explain the concept since they are few in number [1,2]. Research conducted at the secondary school level shows that using manipulatives in the teaching and learning of mathematics are inadequate [3] even though availability of learning materials including manipulatives has been affirmed to be one of the factors that contribute to learners' performance [4,5] and [6] postulate that when learners handle learning objects, it impresses itself in their mind than when they merely see it from a distance. Again, students are not performing in geometry from the basic through to the college level [7,8,9] and it's no different at the international level [10,11]. It is therefore important to focus on geometry starting from the bases (availability of the manipulatives).

A baseline survey with Sandwich B.Ed. Mathematics pre-service teachers at Wesley College of Education in Kumasi shows that most of the materials are not available in their schools. About 95% of these teachers have had College Education. The few who indicated they were present also added they were few. Others who were having a few in their schools also added that they were provided by the Parents Teachers Association and the administration. And a section also said they provide it themselves. From my observation, it was clear that most of these teachers had no idea about the existence of some of these manipulatives, especially the virtual manipulatives like the Geogebra, tangram, etc. These teachers had challenges in identifying topics they could use the few concrete manipulatives they were familiar with to teach. Another challenge was their inability to identify local materials to improvise these materials. All these are an indication that they hardly use or do not use these

manipulatives at all in their lesson delivery at the basic school.

It has been established that effective use of mathematics manipulatives to teach and learn geometry enhances learners' achievement [12] Most of these studies were conducted at the pre-tertiary level [13] and they mainly focus on the use of manipulatives and their impact on students [14]. No empirical study exists on the available manipulatives students use to learn geometry. The few that have been conducted on availability focus on teaching and learning resources which is very broad and it's usually at the basic and senior high schools [15,16,17]. It is these gaps in the literature that the present study seeks to bridge.

Geometry is an area in mathematics that involves points, lines, angles, and space and their nature, properties, measurement, and relationships. According to [18], geometry can be considered as a "science that deals with the properties and relations of lines, angles, surfaces and solids" (p. 14). Geometry is believed to have started from ancient Egypt. Knowledge was acquired by measuring the lands around the Nile River [19]. "Every unit whether it is built around a particular kind of geometric property will aim at the understanding and mastery of several kinds of things" (Charles et al. cited in [20]. The primary role of a classroom instructor is to furnish learners with a conducive learning environment where learners can maximize the available opportunities to attain desired understanding which will help in achieving the instructional objective. For instance, a ruler and protractor may be used to maximize learners' understanding of measurements by providing data for the experimental study of geometric figures and their features. Drawings on the board with an explanation of concepts can clarify many ideas.

Construction, visualization, and justification of concepts in geometry are a challenge for many senior high teachers in Ghana. This is as a result of the conventional method of teaching adopted in most of our institutions. The primary characteristics of the conventional method of teaching are teacher-centeredness and recall. In the area of geometry, it makes learners passive listeners and limited in analysis and reasoning, [21] These hinder teachers from discussing, interacting with one another. Skills like exploration and visualization needed to explore geometric concepts are not developed. This results in pre-service teachers' dislike for geometry and hence low achievement [22,23]. Chief examiner's report of WASSCE shows that candidates perform poorly in geometry especially in the area of circle theorem [8]. The report states that a very small percentage of candidates of WASSCE attempt circle theorem questions. The few who attempted were unable to solve the questions [24].

One of the main causes of pre-service teachers' poor performance in geometry is the teacher's use of the conventional method of teaching and unavailability of teaching and learning resources [25]. Other factors include teachers' anxiety for geometric concepts, and also some primary school textbooks contain little information on geometry. Hence, pre-service teachers who can climb up the academic ladder usually have a weak foundation in Geometry [26]. Perhaps one way of resolving this issue is to motivate facilitators to integrate technology in mathematics lessons at the college level to make Geometry more real than it is presented. This will serve two purposes: learners will get the needed comprehension of geometry and integrate ICT in their classroom to build their understanding of Geometry.

Manipulatives on the other hands are defined as "objects that appeal to several senses and that can be touched, moved about, rearranged, and otherwise handled by children" [26]. For this study, mathematics manipulatives are virtual or physical objects and help students increase their understanding of mathematical concepts [27]. Manipulatives are not only limited to objects that can be physically felt with our hands. If it can be manipulated whether physically or on the screen.

Manipulatives can be put into two broad groups; the Virtual (dynamic and static) and the concrete (both 3 and 2 dimensional) [28]. The static virtual manipulatives are visual images of the concrete manipulatives that are shown as pictures on the screen [29]. These types of manipulatives cannot be manipulated. The dynamic manipulatives are found on the screen and they can be manipulated just as the concrete manipulatives with the curser [29]. The 2D concrete manipulatives are the pictorial representation or sketch of the physical manipulatives. They can only be seen and not manipulated. The 3D concrete manipulatives are the physical manipulatives that have length, breadth, and height. They can be used for hands-on activities.

Manipulatives in any form must be used in teaching at all levels, especially in the field of mathematics. Manipulative use can greatly improve the learning and teaching of any subject in the school curriculum. According to [30], knowledge discovered by pre-service teachers through the use of manipulatives stays with them for long as compared to the one imparted by the teacher. [31] added that if a teacher uses appropriate manipulative to support his or her teaching, it enhances the pre-service teachers' innovative and creative thinking and also, helps them to become more enthusiastic in learning the subject.

However, the mere use of manipulatives should not be viewed as the solution to pre-service teachers' challenges in the learning of mathematics [32], but rather both teachers and learners have to make useful meaning out of the manipulative being used [33]. If this is not considered, manipulatives will only be seen as an entertainment tool and nothing else at the end of lesson delivery. As a result, there is a need for educators to have insight into the 'when', 'why', and 'how' manipulatives are used [13]. Kelly further stated that for the teacher to achieve the learning objective, he or she has to elaborate further on the target of the session to the learners before its use. When manipulatives are used for long they result in pre-service teachers easily assimilating the abstract mathematical concept and leading to an increase in learner's achievement.

[34] in their unpublished paper investigated pre-service teachers' perception of the use of phones to learn mathematics. In their study, it was found that 94% of them are using android phones. [35] unpublished thesis on pre-service teachers' mathematics performance through the use of manipulatives found that though all the four colleges of education in the Northern Region have ICT laboratory they are not installed with mathematics applications. ICT and Mathematics have been put together as a department but it seems they still operate as individual entities.

The purpose of this study therefore is to investigate the available manipulatives students in college use to learn geometry. This includes both concrete and virtual manipulatives. Also, gather information on how the department come by these available manipulatives and their storage. Investigating the availability of manipulatives at the college is of important significance. First, the availability of these manipulatives will give a higher probability that tutors and students are going to use it to facilitate teaching and learning [36]. This will improve their performance in geometry. Also, pre-service teachers will be familiar with these manipulatives and know how to use it. Being familiar and knowing how to use it, gives a higher probability that, they will use it on the field when they are available at the basic school. It will also motivate them to improvise it and use when it's not available. This will improve students' performance in geometry at the basic school, therefore laying a stronger foundation for further education for these students.

2. Research Questions

The study provides answers to the following research questions;

1. What are the concrete manipulatives available in the colleges for students to learn geometry?
2. What are the virtual manipulatives available in the colleges for students to learn geometry?
3. How does the department obtain these available manipulatives that tutors and students use in teaching and learning geometry?

3. Methodology

The research was conducting in Northern Ghana taken data from Three Colleges of Education. The 46 Colleges of Education in Ghana are grouped into five zones; Ashanti/ Brong Ahafo Zone, Northern Zone, Volta Zone, Eastern/ Greater Accra Zone, and Central and Western Zone. Among these Zones, the Northern Zone have the second highest number of colleges (10). Among the five Regions in the Northern Zone, the Northern region have four of the 10 colleges of education in the zone. Out of the 4 colleges, 3 of them are old colleges which have been in existence for not less 58 years. Hence it is necessary to conduct such a study in the Northern Region.

There are four public colleges of education in the Northern region of Ghana. They are St Vincent College of Education at Yendi; E.P. College of Education at Bimbila; Tamale and Bagabaga College of Education in Tamale. From these four Colleges of Education, three were purposively sampled for the study. The three that were selected were E.P. College of Education at Bimbila; Tamale College of Education and Bagabaga College of Education. These were selected because they are ranked among the oldest Colleges of Education with each having been in existence for more than twenty years. Besides, these Colleges are expected to train teachers of Mathematics as part of their mandate in training teachers in Ghana. It was therefore imperative that such institutions were selected for any research concerning the training on teaching of mathematics.

The mixed method design was adopted for the study. This design allowed for variation in collecting the data and as observed by [37] has the potential of leading to greater data validity. The last reason for adopting the mixed method design was to answer the research questions from different perspectives. This article forms part of a broader research on the use of manipulatives in teaching mathematics in Ghana. The first set of data collection involved eight tutors from the three Colleges of Education as follows: One mathematics tutor each from the three colleges, one ICT tutor each from the three colleges and two Heads of Department (HODs) – one each for mathematics and ICT. While the mathematics tutors provided general information on the subject under investigation, the Heads of Department provided insight on the administrative perspective of the phenomenon being studied.

Data were collected using interview guide. The guide consisted of four main questions each with probes and prompts. The interview guide was formulated by the researcher, hence content and construct validity were made. After the formulation of the guide, it was given to colleague mathematics tutors to solicit their inputs. Base on their input the instrument were reviewed. The reviewed instrument was given to a mathematics lecturer at the University for Development final review, taking recommendations from [38], into consideration. [38], observed that for a data collection instrument to be valid and reliable, it must be subjected to critical review by experts at several times and at different levels. The interviews sort information on the type of manipulatives that were available in the department, the number of each of these available manipulatives, how they get these manipulatives, the storage of these available manipulatives, based on the number of available manipulatives, and what method of teaching do they commonly use in teaching mathematics.

The second set of data collection involved 291 second-year pre-service sampled from a total of 1,200 second-year pre-service sampled from the three colleges of education using [39] sample selection guide. In each of the three colleges, 97 second years were randomly selected for the study. Hence the sample size was 291. The first years were not considered in this study because of their low level of familiarity with the college system which could have influenced their response. Third years were also not considered because they were on the field doing their teaching practice. It was due to these reasons that only second years were selected for the study. The instrument used to obtain data for the study were checklist and interview guide. The checklist was in two forms. One contained a list of manipulative both concrete and virtual, where students were made to select either available or not available where appropriate. The other was used to collect data on the number of these manipulatives that were available in the department office.

The qualitative data obtained from the interviews were transcribed verbatim. [37], deductive thematic analysis framework was used to analyze and report the themes that emerged from the interviews. For ease of quantitative

analysis, the data collected with the checklist given to the students were analyzed using frequencies and percentages.

4. Results and Discussion

4.1. Concrete and Virtual Manipulative Available in the College

This result is answering research questions 1 and 2, which to find out the manipulatives that are available to learn geometry in the college. To answer these research questions, a checklist was provided to pre-service teachers to indicate whether the listed items were available or not. Respondents were to tick whether the listed manipulatives were available in their college. The listed items comprised both virtual and concrete manipulatives. The results are displayed in Table 1.

Table 1. Availability of Manipulatives in the Colleges of Education

Mathematics Manipulatives	Available	Not Available	Number Available
1. Concrete Manipulatives			
a. Geometry Manipulatives			
Geoboard	152 (52.2%)	139 (47.8%)	4
Tangram	0 (0.0%)	291 (100%)	0
3D shapes	0(0.0%)	291(100%)	0
2D shapes	0(0.0%)	291(100%)	0
Graph board	231(79.4%)	60 (20.6%)	1
Geometric Construction Instruments	208(71.5%)	83 (28.5%)	2
b. Other mathematics Manipulatives			
Abacus	148 (50.9%)	143 (49.1%)	3
Cuisenaire rod	169 (58.1%)	122 (41.9%)	2
Algebra tiles	148 (50.9%)	143(49.1%)	3
Integer tiles	125(43.0%)	166(57.0%)	2
Fractional tiles	111 (38.1%)	180(61.9%)	2
Counters	262 (90.0%)	29 (10%)	4
Base block	157(54.0%)	134(46.0%)	3
II. Virtual Manipulatives			
a. Geometry Manipulative			
Geogebra App	11 (3.8%)	280 (96.2%)	0
Geoboard	0 (0.0%)	291 (100%)	0
Tangram	0 (0.0%)	291 (100%)	0
3D shapes	0 (0.0%)	291 (100%)	0
2D shapes	0 (0.0%)	291 (100%)	0
Graph board	0 (0.0%)	291 (100%)	0
Geometry	0 (0.0%)	291 (100%)	0
Geometry pad	0 (0.0%)	291 (100%)	0
b. Other Mathematics Manipulatives			
Algebra tiles	0 (0.0%)	291 (100%)	0
Fractional tiles	0 (0.0%)	291 (100%)	0
Counters	0 (0.0%)	291 (100%)	0
Base block	0 (0.0%)	291 (100%)	

From Table 1, more than 50% of the respondents indicated that concrete materials like the Geoboard, geometric construction instrument, and graph board were available in the college while the remaining said otherwise. Among these three manipulatives, it was graph board that 231 (79.4%) of the respondents indicated was available which was the highest. The least was the Geoboard where only 152 (52.2%) of them indicated that was available in the college. For the other geometry concrete manipulatives, all the respondents (100%) indicated that they were not available in the college. Among the other non- geometry concrete manipulatives, counters were seen as the highest available manipulative in the college. Only 29 (10%) of the respondents indicated that it was not available in the college. Few 111 (38.1%) of the respondents indicated that fractional tiles were available in their college. More than 50% of them indicated that non- geometry concrete manipulatives like Abacus, Cuisenaire rod, Algebra tiles, and the base block were available in the college. All these virtual geometric manipulatives can be installed on the phone and the computer. Among them, it was only Geogebra application that a few (3.8%) of them indicated was available in the college while the remaining (96.2%) indicated otherwise. For the remaining virtual geometry manipulatives like Geoboard, Tangram, 3D shapes, 2D shapes, Graph board, Geometry, and Geometry pad, all the respondents indicated that they were not available in the college. The case of the non-geometry virtual manipulatives was not different from the other geometry virtual manipulatives, except Geogebra. All (100%) the respondents indicated that all the listed non-geometry manipulatives were not available in the college.

To confirm the information gathered from the students, the same checklist was sent to the department office to gather information on the number of available manipulatives. Geometry concrete manipulatives like the 2D shapes, 3D shapes, and tangram were not available in either of the departments. The highest geometry concrete manipulative available in the three departments was Geoboard which was 11 in number. Non-geometry concrete manipulatives like an abacus (13), algebra tile (9), and base block (17) were available. Other non- geometry concrete manipulatives available were Cuisenaire rod (8), integer tiles (11), and fractional tiles (7). The highest available non-geometry concrete manipulative was Counters. 21 of them were available in the department. They were in different forms like beads, bottle tops, seeds, buttons and stones, this finding of the study is in line with the findings of [3]. Who found that at the secondary school, though there are several teaching and learning materials they are inadequate. There are 28 mathematics tutors in the 3 colleges, therefore it's possible some may not get access to these manipulatives at one point in time. Due to the inadequate number of manipulatives, the common teaching method is the demonstration which is also in line with the accession of [2,3]. Comparing the sum and the individual frequency of the geometry concrete manipulatives and the non-geometry concrete manipulatives, it is observed that the non-geometry concrete manipulatives are many than the other. Probability, this explains why college students are not performing in geometry [9]. as stated by [4,27]. For the virtual manipulative, both the geometry and non-geometry were not available in the department. Though a greater number of pre-service teachers are found to be using android phones [34], perhaps they are using it for other purposes like entertainment. If used in learning, perhaps use to learn other courses like the reading courses.

To answer the third research question, heads of the mathematics and ICT department were interviewed on how they acquired these available manipulatives. From their responses, they indicated that the college management provided few of the manipulatives they have

in the department. They also indicated that, some students are put into groups for them to improvise and present these materials as a project for assessment. They do that for courses like geometry and algebra. The challenge they mentioned about the student made manipulatives was, they are usually not durable. Since they do it while in school, they are limited to any materials in the environment. Storage of these manipulatives was also a challenge. They indicated that, few of them were stored in the department's office and the rest are kept by the individual tutors. The college tutors also mentioned concrete manipulatives like, counters, fractional tiles, abacus, Cuisenaire rods etc to be available in the college but very few. For virtual manipulatives, they indicated that, the college ICT laboratory computers are not installed with these virtual manipulatives. As a result, most of them only relay on the concrete manipulatives, though they mention some of the virtual manipulatives to the students. Other barriers mentioned to be preventing tutors from using virtual manipulatives was students' unfamiliarity with the gadgets and the application. Lack of data was also another challenge hindering the use of virtual manipulatives in the college. Since the manipulatives are few, they usually use demonstration method to teach. Those that are not available, they resort to explanation of the concept and description of the manipulative.

5. Conclusion

This study examines the availability of both virtual and concrete manipulatives in the College of Education in the Northern region. Also, find out how the mathematics and ICT department acquired the available manipulatives in the department. Data gathered from students, shows that majority of them indicated that more of the concrete non-geometry manipulatives are available to them. For the virtual manipulatives, its only Geogebra that few indicated was available to them. It can then be concluded that there are some mathematics manipulatives in the college. These manipulatives are few and inadequate for both tutors and students. Also, the non-geometry concrete manipulatives are more than the geometry concrete manipulatives. But the worse situation is with the virtual manipulatives, which is almost not available. Lastly, the few available concrete manipulatives were obtained through the effort of the administration and the students' project. From the findings of this study, it can be implied that Tutors are teaching most of the mathematics concepts using the demonstration and lecture method. Also, some mathematical concepts may be taught abstractly. This will affect pre-service teachers' understanding of these topics. They will also not know how to use them in teaching. Hence, they will not use it on the job which can hinder pupils' understanding of mathematics. Pupils will then form weak foundations in mathematics which will affect their further studies in mathematics and mathematics-related subjects.

6. Recommendation

From the study, it is recommended that as studies have shown that the majority of college pre-service teachers are using internet supported phones, tutors should encourage them to use their phones to learn mathematics. By installing these applications on their phones. The administration should organize in-service training for college tutors so they will be abbess with the virtual manipulatives available for learning geometry and other aspects of mathematics. This will help them to use it in their teaching. As a result, pre-service teachers will know them and use them to learn and teach. Though the college mathematic curriculum teaches pre-service teachers how to use mathematics manipulatives to learn and teach it does not teach them how to improvise these manipulatives. That is, how to use the available materials in the environment to improvise these manipulatives. Therefore, there is a need for curriculum developers to relook at the college mathematics curriculum. Lastly, the government should make funds available purposely for the provision of manipulatives for all levels of education, especially geometry.

Availability of Data and Materials

The data that was generated during the study are not publicly available. The reason being that the data were mainly obtained from the field through in-depth interviews. However, the data are available from the corresponding author on reasonable request.

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Competing Interests

The author declares that there are no competing interests.

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