EFFECT OF COGNITIVE GUIDED INSTRUCTION (CGI) ON STUDENTS CONCEPTUAL UNDERSTANDING OF MATHEMATICAL CONCEPT

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Abstract
The world is changing at an increasing pace, so do knowledge, competencies, and skills required for sustainable national development. Therefore, the teaching and learning of school mathematics should emphasize these skills. Teaching for conceptual understanding of mathematical concept has been proven to be one of the routes through which the attributes of the aforementioned skills can be achieved. Herewith, this study sought to investigate the effect of Cognitive Guided Instruction (CGI) on students' conceptual understanding in mathematics. The study was a quasi-experimental design. Simple random sampling was employed to select 298 senior secondary school two (SSSII) mathematics students for the study. Two research questions were posed for the study. Three hypotheses were formulated and tested at 0.05 level of significance. Mathematics Conceptual Test (MCT) developed by the researchers was employed to assess students' level of conceptual understanding. The instrument was an open ended question type of test which allows students to describe, explain, and justify their level of conceptual understanding through discussion, writing, sketching, and matching. Six- facets rubric of understanding designed by Wiggings and McTighe (2005) was employed as a scoring guide to score students' responses to the instrument. A reliability estimate of 0.87 was obtained through Pearson Product Moment Correlation. Data collected were analyzed using mean, standard deviation, and ANCOVA. The findings revealed that students taught with CGI gained more understanding than those taught with conventional method. The findings of the study also revealed that teaching method is a significant factor in developing students' conceptual understanding. The study also showed that CGI can be used for both male and female students. The implication of the study is that mathematics teacher will avoid over-emphasizing of computational procedure at the expense of problem solving skills and conceptual experiences. Based on the findings of the study, it was recommended that mathematics teachers should be trained on how to effectively employ CGI in the classroom. It was also recommended that examination bodies and mathematics teachers should consider examination of mathematical knowledge to include requirements for students to explain and justify connections and relationships among concepts.

Keywords: Cognitive guided instruction, conceptual understanding

Introduction

A nation eager to achieve sustainable development is inclined to make conscious effort and investment towards science and technology. Audu and Amakor (2015) identify in-depth knowledge of mathematics as the underlying spin for advancement in science and technology, which every nation moving towards sustainable development needs to consider. Based on this assertion, it is important for every mathematics students to have a strong grasp of the knowledge

of mathematics in order to appropriately apply it to solve mathematical and everyday life problems, consequently increasing the ability to contribute to the society in which such students belong.

However, many students in mathematics classroom today may have learnt mathematics without much understanding of the math they do. Smith, Bill, & Raith (2018) opined that many students may know procedures to solve mathematical problems, but often lack the understanding of the conceptual basis behind such procedure. This pattern of learning according to DeZeeuw, Craig, and You (2013) could limit students' ability to provide solutions to unfamiliar mathematical problems. According to DeZeeuw et.al (2013), teaching sole computational procedure does not always equip the students with skills to complete tasks outside the classroom. This does not stipulate the teaching of computational procedure to be of no value; rather it emphasizes more attention to the teaching of concept first in order to aid development of procedural fluency. Studies (Tofade, Elsner & Haines, 2013; Ekwue & Umukoro, 2011; Ozsy, 2011) have shown that mathematical knowledge can be expanded when students' conceptual understanding of the subject is deepened. That is, when students understand the conceptual foundation behind the procedure and formulae.

Conceptual understanding in mathematics involves among many other attributes, the students ability to comprehend, explain, interpret, and represent acceptable mathematical concepts or ideas. That is, to know more than isolated facts or methods. Sbar (2018) define conceptual understanding as ″the creation of a robust framework, representing the numerous and interwoven relationship between mathematical ideas, patterns, and procedures″. It implies fostering the ability to strategically connect prior and new information to solve unfamiliar mathematical and real life problems. In a bid to tailor mathematics instructions in these manners and to develop strong conception of mathematical ideas that align with the appropriate mathematical thinking, it is important to view mathematics learning as a social activity which requires students to acknowledge and discuss their mathematical understanding and choice of strategy in a given task (Ginsburg, Lebrecque, Carpenter & Pager, 2015). Adeneye (2011) opines that students learn, and gain more understanding of mathematical concept when they are exposed to learning experiences which afford them the opportunity to communicate their thinking and share the reasoning behind their chosen strategy among their peers and teachers. Findings from the study conducted by Murata, Siker, Kang, Baldinger, Kim, Scott and Laanouette (2017) reveal that a talk-based instruction and students strategy trajectories has a significant effect on students understanding of a taught concept. Also, Hufferd, Kimberly, Fuson,and Sherin (2004) reveal in their study that students who are taught with instructional strategy involving probing questioning has a higher understanding of taught concept than those taught with conventional approach. Mathematics classroom should engage a wide range of interactive activities which require students to think and explain their individual mathematical understanding and choice of strategy. This can be achieved when teachers aim to conceptualize mathematics teaching by exposing students to instructional strategies that teach the underlying structure of mathematical knowledge, and how ideas are related (Smith & Mancy, 2018). Cognitive Guided Instruction (CGI) could be one of such strategies with which true knowledge of mathematics can be achieved.

Cognitive Guided Instruction (CGI) is a process designed for students to think about their own thinking. It is an interactive teaching strategy which allows teachers to facilitate mathematical discourse in the classroom. Wagbada, Treagust, Won, and Chandrasigaran (2016)

describe the strategy as allowing students to have a meaningful conversation about light concept, and it increases the students' understanding of light concept. According to Wagbada et.al (2016), the strategy has tendency to develop the thinking, questioning, and explanation skills needed to master light concepts. Boonen, DeKoning, Jolles, and Van der Schoot (2016) and Cornoldi, Caretti, Drusi, and Tencati (2015) posit that Cognitive Guided Instruction (CGI) encourages productive talk in mathematics classroom where students describe, explain, evaluate and share their strategy or mathematical thinking. It was in support of these findings that the researchers of this study further investigated the efficacy of Cognitive Guided Instruction (CGI) in developing students' conceptual understanding of concepts in mathematics.

Statement of the Problem

Mathematics educators and researchers are seeking ways to develop students' conceptual understanding of mathematics education in and out of the classroom. This was borne out of the need to shift from rote memorization and traditional method of teaching, which have become insufficient for real world learning and application. Teachers cannot possibly exhaust the types of mathematical problems students will encounter in life, it is therefore important for teachers to conceptualize mathematics learning in place of sole teaching of computational procedure. This will enable the students to develop the strategic competence to solve unfamiliar mathematical problems, consequently developing the critical thinking skills require to make correct decisions in a novel situation that might emerged in their everyday lives. To achieve the aforementioned, the teaching and learning of mathematics should emphasize understanding, problem-solving, reasoning, analyzing, and application. There are several empirical evidences of Cognitive Guided Instruction (CGI) on students' achievement in mathematics. Achievement measured in many of these studies was based on students' procedural fluency through the use of closed end type of questions, while ignoring the conceptual foundation for those procedures. As a result of these, there are insufficient empirical evidences about its efficacy on conceptual understanding in mathematics. This study therefore seeks to contribute to the growing body of knowledge on conceptual understanding by investigating the effect of Cognitive Guided Instruction (CGI) on students' conceptual understanding in mathematics.

Purpose of the Study

The aim of the study is to determine the effect of Cognitive Guided Instruction (CGI) strategy on students' conceptual understanding of mathematics. Specifically, the study sought to determine:

1. the students' level of conceptual understanding of mathematical concept when taught with CGI
2. find out the difference in male and female students' level of conceptual understanding of mathematical concept

Research Questions

The following research questions were posed to guide the study:

1. What is the students' level of conceptual understanding of mathematical concept when taught with CGI?
2. What is the difference in male and female students' level of conceptual understanding of mathematical concept?

Hypotheses

Three hypotheses were formulated to be tested at 0.05 level of significance:

1. There is no significant difference between level of conceptual understanding of students taught with CGI and those taught with conventional method.
2. There is no significant difference in male and female students' level of conceptual understanding of mathematical concept.
3. There is no interaction effect of teaching strategy and gender on conceptual understanding of mathematical concept.

Methodology

The study was a quasi-experimental research design. Specifically, it was non-equivalent control group design. It was conducted at Enugu education zone of Enugu State. Simple random sampling technique was used to draw two local government areas out of the three local government areas that made up the zone. This is to give all the LGAs in that zone equal opportunity of being involved in the study. Further simple random sampling technique was used to draw two schools each from the two sampled LGAs making a total of four schools. From each school, one intact class of SSSII mathematics students was randomly selected. The sampled intact classes were assigned to experimental and control group. The sample for this study was 298 SSII mathematics students with 162 for experimental group and 136 for control group.

Instrument used for data collection was Mathematics Conceptual Test (MCT) constructed by the researchers of this study. The instrument was an open ended question type of test which allows students to describe, explain, and justify their mathematical thinking through writing, sketching, and matching. It consists of six probing questions that require the students to provide explicit description and evaluation of relation, connections, and justification of chosen strategies employed in solving mathematical problems. Items of the instrument were based on the mathematical concept taught which are immersed in the following subject areas: algebra, trigonometry, geometry, probability, and statistics. Six-facets of understanding rubric designed by Wiggings and McTighe (2005) was used as a scoring guide to score students responses to each item of the instrument based on the criteria on the rubric. Each item is assigned 5 marks to make a total of 30 marks for the six questions. The 5marks was distributed among the sub-criteria on the scoring rubric for each question as follow; explained (sophisticated and comprehensive – 2 marks, systemic – 2 marks, in-depth – 1 mark), meaningful (insightful – 2 marks, revealing – 2 marks, and perceptive – 1 mark), effective (masterful – 2 mark, skilled – 2 marks, able – 1 mark), in perspective (insightful and coherent – 2 marks, thorough – 2 marks, able – 1 mark), emphatic (mature – 2 marks, sensitive – 2 marks, aware –1 mark), and reflective (wise – 2 mark, circumspect – 2 marks, thoughtful – 1 mark). Face validity was carried out on the instrument by two mathematics experts and an expert in measurement and evaluation to ascertain its clarity and legibility. Estimate of temporal stability was used to determine the reliability of the instrument. MCT was administered on two occasions to a set of students who are not part of the sample for the study. Students' scores from first and second administration were correlated using Pearson Product Moment Correlation and reliability estimate of 0.87 was obtained.

Percentage and mean gain were computed to answer research questions, while analysis of covariance was used to test the hypotheses at 0.05 level of significance.

Results

The findings of the study are presented as follows:

Research Question 1
What is the students' level of conceptual understanding of mathematical concepts when taught with CGI?

Table 1: Mean and percentage mean gain of students' conceptual score

Group	Number of students	Pretest Mean	Posttest Mean	%mean gain
Control	136	15.99	18.51	1.85
Experimental	162	16.57	26.98	6.42

Table 1 showed the mean and percentage mean gain of students in control and experimental group. From the table, it can be seen that the conceptual mean score of students taught with CGI was 16.57 and 26.98 in pretest and posttest respectively, with 6.42% percentage mean gain. Students who were taught with conventional approach had conceptual mean score of 15.99 and 18.51 in pretest and posttest respectively, with 1.85% percentage mean gain. It was further observed that students in experimental group which are taught with CGI have a higher percentage mean gain. This implies that students taught with CGI perform better than students taught with conventional approach.

Research Question 2
3. What is the difference in male and female students' level of conceptual understanding of mathematical concept when taught with CGI?

Table 2: Mean and percentage mean gain of male and female students' conceptual score in experimental group

Gender	Number of students	Pretest Mean	Posttest Mean	%mean gain
Male	80	14.99	23.97	11.23
Female	82	16.45	26.67	12.46

Table 2 showed the mean and percentage mean gain of male and female students' conceptual score in experimental group. From the table above, it could be 400.75 with exacted probability value was less than 0.05 set as level of significance, the null hypothesis (H_O) was rejected. Thus the inference was that, there is a significant difference in the level of conceptual understanding of mathematical concept of students seen that mean conceptual score of male students was 14.99 and 23.97 in pretest and posttest respectively, with percentage mean gain of 11.23%. The female students had the mean conceptual score of 16.45 and 26.67 in pretest and posttest respectively, with percentage mean gain of 12.46%. It was further observed the female students have a higher percentage gain than the male students when taught with CGI.

Hypothesis 1

There is no significant difference between the level of conceptual understanding of students taught with CGI and those taught with conventional method.

Table 3: Analysis of Covariance (ANCOVA) of interaction effect of teaching strategy and gender of students' conceptual score in CMT

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Dec.
Corrected Model	2420.540[a]	4	605.135	192.227	.000	
Intercept	2661.362	1	2661.362	845.406	.000	
Pretest	929.586	1	929.586	295.291	.000	
Method	1262.431	1	1261.431	400.705	.000	S
Gender	2.953	1	2.953	.938	.334	NS
Method *Gender	14.434	1	14.434	4.585	.033	S
Error	922.372	293	3.148			
Total	1888694.000	298				
Corrected Total	3342.913	297				

S = significant, NS = not significant at $p < 0.05$

The result in Table 3 revealed that an F-ratio of 400.705 with exact probability value of 0.00 was obtained. Since the exact probability value was less than 0.05 set as level of significance, the null hypothesis (H_{O1}) was rejected. Thus the inference is that, there is a significant difference in the level of conceptual understanding of mathematics concepts of students taught with CGI and those taught with conventional approach in favor of CGI group.

Hypothesis 2

There is no significant difference between the male and female students level of conceptual understanding mathematics concepts.

The result in Table 3 also revealed that an F-ratio of 0.938 with exact probability value of 0.334 was obtained. Since the exact probability value was greater than 0.05 set as level of significance, the null hypothesis (H_{O2}) was not rejected. Thus the inference was that, there is no significant difference in the male and female level of conceptual understanding of mathematics concept when taught with CGI. This also implies that gender is not a significant factor in determining students' level of conceptual understanding in mathematics.

Hypothesis 3

There is no interaction effect of teaching method and gender on students' level of conceptual understanding of mathematics concepts.

Table 3 further presents the result of interaction effect of teaching method and gender of students on conceptual level of understanding. An F-ratio of 4.585 was obtained with exact probability value of 0.033. Since the probability value of 0.033 is greater than 0.05 set as level of significance, the null hypothesis (H_{o3}) was rejected. Inference drawn therefore is that, there is no interaction effect of teaching method and gender on students' conceptual change in mathematics.

Discussion

Results of the study presented above showed that conceptual mean score of students taught with CGI was higher than those of the students taught with conventional approach. This finding agrees with the study of Audu and Amakor (2015) where the students in metacognitive group retained more knowledge of mathematics concept than the control group. Findings from the test of hypotheses confirmed that teaching methods were a significant factor on students in developing students' conceptual understanding. The finding is consistent with the studies conducted by Murata *et al* (2017) and Hufferd *et al* (2004) where the students taught with instructional strategy involving probing questioning displayed higher understanding of mathematics concept than those taught with conventional approach. The finding also agrees with the study of Wagbada, Treagust, Won, and Chandrasigaran (2016) where students taught with metacognitive strategy gained more understanding than those taught with convention.

The finding from the study also revealed that CGI strategy seems to have improved the conceptual understanding of male and female students but did not significantly affect the level of conceptual understanding gained by the students. This was evident in the noted difference between male and female level of conceptual understanding which was not statistically significant.

The use of CGI proved to be more effective in enhancing students' level of understanding of mathematics concepts. The implication of this is that, mathematics students will perform better both in internal and external examinations, and develop the competencies and skills needed for national development. Also, mathematics teachers who adequately use CGI to teach will improve their knowledge on how to tailor instructions towards students' math mind. Furthermore, the use of CGI will guide curriculum experts to structure mathematics curriculum towards achieving sustainable national development.

The study however is subjected to limitations such as students dropping out of the study before the end of the experiment. Some students completed pretest only, while some students completed posttest only. These categories of students were dropped thereby reducing the sample size, and this may affect the generalization of the study to other areas.

Conclusion

The results obtained from this study indicated that Cognitive Guided Instruction (CGI) has the tendency to develop in students the skills required to succeed both in mathematics and in their everyday lives. Findings of this study have shown that CGI can significantly increase students' conceptual understanding in mathematics. The finding further implies that the strategy can be use for both male and female students. Therefore the use of CGI in mathematics classroom holds a great promise of helping students to have a strong grasp of the knowledge of mathematics.

Recommendations

The following recommendations were made for consideration and implementation;

- Mathematics teachers should endeavor to use CGI in mathematics classroom
- Mathematics teachers should avoid over-emphasizing on fast fact recall at the expense of problem solving and conceptual experiences.
- Examination bodies and mathematics teachers should consider examination of mathematical knowledge to include requirements for students to explain and justify connections and relationships among concepts.
- School curriculum planners should adjust the curriculum for the inclusion of CGI

- Trainings and workshops on effective use of CGI should be organized for mathematics teachers.

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