

# **Effect of Concept Mapping Strategy on Students' Achievement in Junior Secondary School Mathematics**

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**Abstract**—This study investigated the effect of concept mapping strategy on achievement in mathematics of 88 junior secondary year three Nigerian students. The study adopted a pre-test, post-test non-equivalent control group quasi-experimental design and data collected for the study were analysed using the t-test statistic. The experimental group, taught with concept mapping strategy obtained mean post-test score which was significantly higher than the mean post-test score of the control group. Results showed that concept mapping is an effective strategy for teaching and learning mathematics. The strategy is also capable of improving students' mastery of content at the higher-order levels of cognition. Based on the findings, the study recommended that concept mapping should be added to the teaching strategies of mathematics teachers at the secondary school level.

**Keywords**— Concept mapping, students' achievement, analysis level of cognition, synthesis level of cognition, evaluation level of cognition, higher-order abilities.

## 1. INTRODUCTION

Since the new millennium in Nigeria, there has been a radical shift in views of primary and secondary schools teaching and learning. New curricula have been developed that emphasize the development of autonomous learning capabilities in students, or help students learn to learn, by developing their generic skills and interest [4] in active inquiry-based constructivist instructional environments. Within the constructivist paradigm, the focus is on the learner rather than the teacher. As the learners interact with their environment, they gain an understanding of its features, construct their own conceptualizations and find solutions to problems, mastering autonomy and independence. In constructivism, learning is the result of individual mental construction in which learners match new against given information to establishing meaningful connections. It is expected that students' learning of mathematics through doing mathematics, using realistic instructional techniques should enhance the inculcation of the generic skills of inquiry, reasoning, conceptualizing, problem-solving and communicating. By applying these skills, students are not only expected to construct their knowledge of mathematics but also to establish confidence and positive attitudes toward

mathematics. One way of achieving this may be through the adoption of student-centred, activity-based and minds-on approaches that cater for individual needs and differences, learning styles, interests and abilities. One such student-centred, inquiry-based approach to organize learning is concept mapping. Concept mapping is a metacognitive learning strategy used in measuring individual's knowledge structure and organization in a specific domain of knowledge. Metacognition refers to "cognition about cognition" or "knowing about knowing" [23] or "thinking about thinking". According to [12], metacognition refers to one's knowledge concerning one's own cognition processes or anything related to them, e.g., the learning-relevant properties of information or data. A number of definitions of the term "concept mapping" might be necessary at this point.

Concept mapping, according to [21] "is a technique used to represent the relationships among concepts in a two-dimensional graph" (p. 921). Concept mappings are a procedure that is used to measure the structure and organization of an individual's knowledge [25, 31]. A concept mapping represents a collection of interconnected concepts with specified relationships between pairs of concepts identified on the links connecting them [8]. Concept mappings are spatial representations of concepts and the interrelationships that are intended to represent the knowledge structures that humans store in their minds [16].

Concept mapping as a method to visualize the structure of knowledge [2] was originally developed by Novak and the members of his research group as a means of representing frameworks for the interrelationships between concepts [25, 32] and as an instructional and assessment tool to facilitate meaningful learning [21]. Concept maps as originally developed have been grounded in [3] assimilation theory of cognitive learning which focuses on individuals and how they integrate new learning into existing conceptual frameworks [25] by making explicit, conscious connections between concepts as a way to integrate information into memory [1, 6, 35]. [3] is of the position that cognitive structure is organized hierarchically with new concepts or concept meaning being subsumed under broader, more inclusive concepts. However, the basic element of a concept map as given by [33] consists of concept words or phrases that

are connected together with linking words or phrases to form complete thoughts called propositions. Concept maps are built by placing terms, which represent the concepts to be mapped in structures called nodes. The nodes, which are linked together into propositions, show how students connect or link concepts. The propositions are represented by arrows to connect individual concepts together. The directionality of the link is indicated by arrow. The conceptualization of the materials by the students is indicated by the directionality and the connecting proposition. The proposition, thus illustrates the contextual relationship of the concepts to each other.

The basic premise of concept maps has been representation of knowledge in a hierarchical form. The hierarchical structure as strongly supported by [26] has been questioned as the only means of linking concepts together [31] and one suggestion has been that the structure of the map should allow the structure of the knowledge and not the other way around [8]. Several types of structures have been proposed such as hierarchy, cyclic chain, spider-maps, and networks that could be used to mentally represent the knowledge embedded in one's long-term memory. Since the knowledge expressed in the maps is mostly semantic, concept maps are sometimes called semantic networks. The two ways of constructing concept maps are the traditional paper and pencil [2] and the computer-assisted concept mapping systems [10]. Concept mapping tools are computer-used, visualizing tools for developing representations of semantic networks in memory [2]. Often it is claimed that concept mapping tools enable the right level of complexity and detail in the student's exploration [18] and Programs such as SemNet, Learning Tool, Inspiration, Mind Mapper, etc have been developed for use as concept mapping tools.

Previous uses of concept maps entail that concept mapping has been used as a diagnostic tool to assess students' conceptions [24, 30, 36], for clarifying students' understandings and making connections between concepts explicit [22] as an alternative science classroom achievement assessment [14, 33, 34] and for assessing learning processes [13]. Reference [13] proposed concept mapping to assess students' learning in the three phases of a learning cycle (exploration, conceptual invention, and expansion). Concept mapping has been claimed to be valid in assessing students' conceptual changes. For example in [36] study, concept mapping was used as both a pre-test and a post-test, and the capability of concept mapping to identify students' conceptual change due to the treatment effect (concurrent validity) was studied. They found students' concept maps were substantially different in complexity and propositional structure of the knowledge base from the pre-test to the post-test and concluded that concept mapping is a valid tool to document students' conceptual change.

Reference [11] investigated the use of concept mapping as an "advance organizer" for eight-grade students in a science unit. They reported significant differences in performance of a concept mapping group at the end of the unit over a control group that did not use concept mapping.

Reference [7] investigated the effect of concept mapping on primary school students' understanding of the concepts of the force and motion. The result showed that there was a significant difference between the mean scores of experimental and control groups but gender had no significant influence on their understanding. Reference [22] investigated the effect of concept mapping construction in college chemistry laboratories. They reported that students had a strong positive attitude toward the use of concept mapping despite the lack of difference in performance on multiple choice assessment tests between the experimental and control groups. Reference [9] investigated the effects of concept and vee mappings on students' cognitive achievement in ecology and genetics. Total of 808 tenth grade students were involved in the study. The results showed that the experimental groups performed better than the control group.

Reference [29] investigated the effect of using the concept mapping strategy in teaching on the achievement of fifth graders in science. The result of the study showed that concept mapping strategy results in higher achievement. Two studies compared concept mapping to other forms of knowledge representation with respect to learning new material. Reference [19] compared concept mapping to lists and outlines such as those used for lecture aids, and assessed differences in students' recall of the presented material. They reported no significant difference between the effect of concept mapping and the other two lecture aid forms. Contrary to this result, [15] reported a significant difference in the recall of material presented in the form of a concept mapping when compared to a normal text presentation for only one of the two subject domains tested. Studies on what constitutes a concept mapping raise more questions than they answer, especially regarding the usability and suitability of concept mapping in different contexts. Conflicting conclusions have been produced while inconsistent results have also been reported in the literature on the effect of concept mapping strategy on students' learning outcomes. Hence, one aim of this study was to investigate the effect of concept mapping on students' achievement in mathematics. Another aim of the research effort presented here was to investigate the effect of concept mapping on students' achievement in higher order abilities in junior secondary school mathematics.

A related research has been carried out by [27] in which they claim that the low correlation between concept mapping scores and traditional test scores demonstrates that concept mapping and traditional tests measure different attributes of students' abilities. More specifically, they claim that concept mappings assess higher-order abilities (analysis, synthesis and evaluation) while traditional assessment assesses lower-order abilities (knowledge, comprehension and application). This claim, according to [21] is not convincing because the contents and formats of the traditional tests were not described in the paper. Reference [28] argued that it is possible to measure indirectly higher-order abilities using

appropriately designed traditional test formats such as multiple-choice items.

II. RESEARCH QUESTIONS

This study sought to find answers to the following questions:

- Will there be any significant difference between the pre-test achievement scores of students exposed to the concept mapping strategy and those exposed to the regular teaching method?
- Will there be any significant difference between the post-test achievement scores of students exposed to the concept mapping strategy and those exposed to the regular teaching method?
- Will there be any significant difference between the students' analysis, synthesis and evaluation levels of cognition after being exposed to the concept mapping strategy and the regular teaching method?

III. THE CONCEPTUAL FRAMEWORK

The conceptual framework to guide the study was based on the systems Approach [17]. This approach holds that the teaching and learning process has inputs and outputs. The study was also based on the assumption that students' poor performance is a function of the quality of instruction and not lack of students' ability to learn [5, 20]. The framework is represented diagrammatically in figure 1. Figure 1 shows the relationship of variables for determining the effects of using concept mapping strategy on secondary school student' achievement in mathematics. Learning outcomes represent the dependent variables and are influenced by various factors. These factors include: learner characteristics, classroom environment and teacher characteristics as revealed in figure 1. These are called extraneous variables which needed to be controlled. Teacher training determines the teaching strategy a teacher adopts and how effective the teacher will use the strategy. The teaching of the subject matter is a function of the learners' age and their class level. The type of school as a teaching environment affects the learning outcomes. This study involved trained mathematics teachers to control the teacher variable. The type of school used was co-educational to control the effect of the classroom environment. Junior secondary year three students who are of similar age were involved in the study. Thus, in this study the teaching method used influenced the learning outcomes.

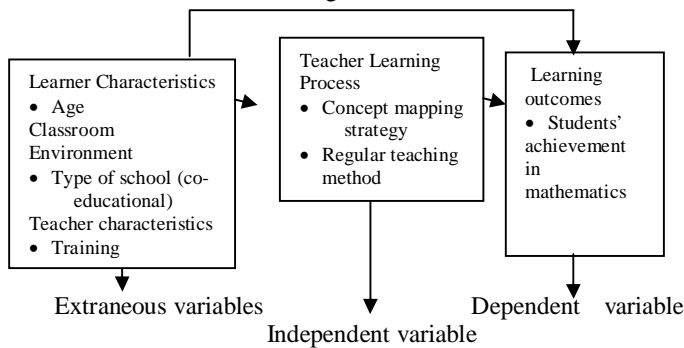


FIG. 1 THE CONCEPTUAL FRAMEWORK

IV. METHODOLOGY

1) *Research design:* This study adopted a pre-test, post-test non-equivalent control group quasi-experimental design. This is because there was non-random selection of students to the groups. Secondary school classes exist as intact groups and school authorities do kick against any attempt to dismantle and reconstitute them for the purpose of research since this will disrupt school academic calendar.

The diagrammatic representation of the design is shown in Figure 2.

<b>Experimental group</b>	O <sub>1</sub>	X <sub>1</sub>	O <sub>2</sub>
<b>Control group</b>	O <sub>3</sub>	X <sub>2</sub>	O <sub>4</sub>

where O<sub>1</sub> O<sub>3</sub> represent pre-test

O<sub>2</sub> O<sub>4</sub> represent post-test

X<sub>1</sub> represents treatment (concept mapping strategy)

X<sub>2</sub> represents treatment (regular teaching method)

FIGURE 2. PRE-TEST, POST-TEST NON-EQUIVALENT CONTROL GROUP RESEARCH DESIGN.

2) *Sample and sampling procedure:* Purposive sampling technique was used to select two schools that participated in the study. The two schools chosen were those that have between 30 and 45 students each in their junior secondary school (JSS) year three classes. Thus, a sample of eighty-eight (88) JSS year three students (45 males and 43 females) participated in the study. The two classes of eighty-eight students were then assigned randomly into an experimental class and a control class. The mean age of participants is 13 years.

3) *Course Content Selection:* The topics in plane shape and angles in a polygon aspect of JSS year three mathematics curriculum covered in this study are limited to parallelogram, rhombus, kite, angles between lines, angles in a quadrilateral and polygons. These topics were selected because each can be taught at analysis, synthesis and evaluation levels of Bloom taxonomy Reference [37].

4) *Instrumentation:* One instrument named the Mathematics Achievement Test (MAT) was used in collecting data for the study. The MAT is a 20-item multiple-choice objective test items with one key and three distractors. The MAT was constructed and validated by the researcher to measure students' achievement in mathematics covering the selected topics covered in the study. The MAT was based on appropriate analysis, synthesis and evaluation levels of cognitive domain. The first 7 items of the validated instrument covered analysis skills, the next 7 items covered synthesis skills while the last 6 items measured evaluation skills. To test the reliability of the instrument, the 20-item MAT was administered on a sample of 30 students (15 males and 15 females) in a school that was not part of the study but whose students' demographics in terms of age and class level were similar to the students involved in the main study. From the students' responses, a reliability coefficient of 0.78 using the

Kuder-Richardson method (Formula 21) was recorded. The test items showed discrimination power of more than 0.40 and difficulty index of 0.40 – 0.60.

5) *Procedure:* The two mathematics teachers in the selected schools served as the instructors for the students that took part in the study. Both teachers were trained for one week on how to administer the intervention and control treatments. Before treatment that lasted for three weeks, the MAT was administered to the experimental group and the control group at the same time as pre-test. Thereafter, the two groups were taught by their respective instructors for the duration of the instructions. The participants in the experimental group were exposed to a short lesson on concept mapping and the proper procedures for creating concept maps. Shortly thereafter the participants were placed into groups of three and given a short activity in the class to ascertain if they understand the process of concept mapping. Once this was complete the teacher introduced the lesson and the objectives for learning to the experimental group and then lecture. Concept mapping process began with a discussion session. In the control group, the teacher introduced the lesson and the objectives for learning and thereafter taught the participants without concept mapping but with lesson plan which involved lecture. Both experimental and control groups were not aware that they were being involved in a study. Although each group was taught by a different instructor, efforts were made to reduce differences in teaching styles and undue enthusiasm on the part of instructors by having them plan their lessons together, use the same textbooks, teaching aids and tests. Also, the instructors used the same length of time to teach each topic. The items in the pre-test instrument were rearranged and re-administered on both groups, as post-test, at the end of instructions to assess the learning that had taken place. The post-test was administered on both groups in the fifth week. The researcher scored the pre-test and post-test and generated quantitative data, which were analysed.

6) *Data Analysis:* The multiple-choice objective test scores were corrected for guessing by means of the formula:

$$\text{Test Score} = R - \frac{W}{K - 1} \text{ where}$$

R = number of items the students got right

W = number of items the student got wrong

K = number of alternatives in the multiple-choice test item.

The independent-samples t-test was used to compare means for the two groups on the pre-test, post-test, and on the analysis, synthesis and evaluation components of the test for possible test of significant difference. Significance level of 0.05 was used.

## V. RESULTS

TABLE 1  
DIFFERENCE BETWEEN THE STUDENTS' PRE-TEST ACHIEVEMENT SCORES

Group	N	$\bar{x}$	SD	Df	t	Non-
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						sig.
Experi.	45	11.42	2.68	86	0.106	0.31
Control	43	11.48	2.63			

Non-significant at  $p > 0.05$ .

TABLE 2  
DIFFERENCE BETWEEN THE STUDENTS' POST-TEST ACHIEVEMENT SCORES

Group	N	$\bar{x}$	SD	Df	t	Sig.
Experi.	45	16.72	3.52	86	4.907	0.00*
Control	43	13.01	3.57			

\* Significant at  $p < 0.05$ .

TABLE 3  
DIFFERENCE IN THE STUDENTS' POST-TEST ANALYSIS, SYNTHESIS AND EVALUATION SCORES

Taxonomy	Group	N	$\bar{x}$	SD	Df	t	Sig.
Analysis	Experi.	45	5.82	1.32	86	6.38	0.00*
	Contr.	43	4.01	1.34			
Synthesis	Experi.	45	6.84	1.53	86	9.38	
	Contr.	43	4.07	1.23			
Evaluation	Experi.	45	5.72	1.36	86	5.27	
	Contr.	43	4.22	1.31			

\* Significant at  $p < 0.05$ .

The results obtained in this study are presented in accordance with the research questions raised to guide its investigation.

**Research Question 1:** Will there be any significant difference between the pre-test achievement scores of students exposed to the concept mapping strategy and those exposed to the regular teaching method?

Table 1 shows the means and standard deviations of the pre-test scores of the two groups. The result showed an insignificant outcome ( $t = 0.106$ ,  $p > 0.05$ ). This implied that the pre-test mean score of the students in the experimental group is not significantly different from that of the students in the control group at the 0.05 confidence level.

**Research Question 2:** Will there be any significant difference between the post-test achievement scores of students exposed to the concept mapping strategy and those exposed to the regular teaching method?

Table 2 shows the means and standard deviations of the post-test scores of the two groups. Comparison of the difference between the post-test mean scores of the two groups produced a significant outcome ( $t = 4.907$ ,  $p < 0.05$ ). This result implied that the students in the experimental group obtained significantly better post-test achievement scores than their counterparts in the control group.

**Research Question 3:** Will there be any significant difference between the students' analysis, synthesis and evaluation levels of cognition after being exposed to the concept mapping strategy and the regular teaching method?

Table 3 shows the means and standard deviations of the students' post-test scores in the analysis, synthesis and evaluation levels of cognition of the two groups. The results showed significant outcomes in the students' scores at analysis level ( $t = 6.38, p < 0.05$ ), synthesis level ( $t = 9.38, p < 0.05$ ) and evaluation level ( $t = 5.27, p < 0.05$ ) of cognition. These outcomes showed that the students exposed to the concept mapping strategy significantly achieved better than those exposed to the regular teaching method at their analysis, synthesis and evaluation levels of cognition.

## VI. DISCUSSION

The results of the present study showed that the pre-test mean score of the students in the experimental group was not significantly different from that of the students in the control group. This indicated that the two groups used in the study exhibited comparable characteristics. Hence, they both entered the instruction/experiment on equal strength. This goes to show that the two groups were suitable for the study when comparing the effects of concept mapping strategy with the regular teaching method on achievement in mathematics. Again, this is a confirmation that if any observable significant difference is seen in the post test mean scores of the two groups then such difference would not be attributed to chance but the effect of the intervention which is the concept mapping strategy.

However, the post test mean score of the students in the experimental group was found to be significantly different from that of their counterparts in the control group. This finding has again shown the efficacy of the use of concept mapping strategy in enhancing students' achievement in mathematics. This finding, though not in agreement with the outcome of similar studies conducted by [22] in chemistry and [19] is however corroborating the studies of [2, 9, 29] which showed that concept mapping strategy was more effective in increasing students' achievement on multiple-choice assessment test than the regular teaching method. The noticeable impact of concept mapping on students' achievement recorded in this study may be attributed to the characteristics inherent in the use of concept mapping. Concept mapping offers another means to create the necessary "mind-on" environment that differentiates coherent mathematics instruction from a series of isolated activities. In this study students were able to comprehend concept meanings, organize concepts in hierarchy and form meaningful relationships between concepts to arrive at a coherent, integrate network of the material learned. This no doubt could enhance learners' memory and recall for the material learned.

Research evidence has indicated that pieces of information are better remembered by students when they are communicated and learned verbally and visually. Concept mapping combines visually learning with spatial representation of information to promote meaningful conceptual learning. Visual learning according to [2] is

absorbing information from illustrations, photos, diagrams, graphs, symbols, icons and other visual models. No wonder in this study students were able to focus on meaning, recognize and figure out relationship between concepts and this may have enhanced better students' achievement in the concept mapping group.

An interesting finding in this study is the obtained significant differences between the experimental group and the control group at the higher levels of mastery. This finding is consistent with the claims that concept mapping assesses students' structural knowledge which mediates the translation between declarative knowledge and procedure knowledge [16] and higher order abilities (analysis, synthesis and evaluation) [27] which possess some degree of transferability [21]. One likely explanation for this finding is that concept mapping enabled the students to break down complex concepts into component sub-concepts to see relationships for clarity and at the same time putting together these sub-concepts with linking words to form an integrated meaningful whole. Besides these skills, students were able to make value judgments about arrangement of the concepts and assess the appropriateness of the linking words. All these may have enhanced the better performance of the concept mapping group.

Specifically, this study investigated the effect of concept mapping strategy on students' mathematics achievement in higher-order cognitive abilities at the junior secondary school level. The study adds to the accumulating body of knowledge regarding the effectiveness of concept mapping strategy in promoting students' achievement in mathematics classroom. The results of the study showed that concept mapping is an effective strategy for teaching and learning mathematics at the junior secondary level. Also, the strategy has the capacity to foster mastery of content at the higher-order cognitive.

This study has implications especially for mathematics teachers in Nigeria where mathematics curriculum is being restructured and redeveloped with much emphasis on concept attainment. Adopting concept mapping strategy in mathematics classes will aid students to develop better understanding of important concepts. This was demonstrated in this study as students were able to figure out relationships between concepts, create meaning schemes and construct knowledge bases. In this way students would be much better prepared to face future mathematics courses.

A major preoccupation of mathematics teachers has been changing from traditional teaching approaches that emphasize rote learning to student-centred, activity-based, minds-on approaches that promotes meaningful learning. Adopting concept mapping requires that mathematics teachers have a good knowledge of constructivist learning and the ways in which concept mapping can be used to foster students' thinking. However, adopting concept mapping strategy in mathematics classes calls for a new role on the part of teachers. Such new roles as learning and constructing meaning should be encouraged at the expense of the other roles as telling, instructing and dictating information which

are less motivating and incompatible with the constructivist theory of learning.

In conclusion, this study can be replicated with larger sample size and the possible effects of gender differences and cultural bias evaluated. This would determine the most efficient means of using concept mapping for students' benefit.

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