Thinking Maps as Benchmarking Tools for Basic Science and Technology Instruction: Implication for Sustainable National Development

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Abstract
This study investigated the use of thinking maps in teaching basic science and technology concepts in junior secondary schools in Kanam, Plateau State, Nigeria and its implication for sustainable national development. One hundred and twenty junior secondary two school students constituted the sample (with 60 students in the experimental and control groups from one urban school and one rural school). The sample was selected from a population of 1,210 students distributed among 24 public junior secondary schools in Kanam local government area, Plateau State. Two research questions and two null hypotheses guided the study. The pre-test, post-test non-equivalent control group design was employed. A Basic Science and Technology Achievement Test developed by the researcher was used to collect data from the students.The research questions were answered using mean and standard deviation while the hypotheses were tested using t-test statistics at 0.05 level of significance. Results of the study revealed that there was a significant difference between the basic science achievement post-test mean scores of students exposed to thinking maps and those not exposed to the maps. Furthermore, a significant difference was found between Basic Science and Technology Achievement post-test mean scores of students in urban and rural schools taught with thinking maps. The implication of the findings was that, teachers should use appropriate teaching strategies and tools such as thinking maps to enhance students' engagement, critical thinking and problem-solving skills which are vital for improving achievement in Basic Science and technology as well as sustainable national development.

Keywords: Thinking Maps, Benchmarking Tools, Basic Science and Technology, Instruction, Sustainable National Development

Introduction

The world today is predominantly shaped by overwhelming impact of science and technology so much that every aspect of human behaviour has been modified due to its influence. Nations of the world today therefore, cherish science and technology due to its impact on national development. It is as a result of the significant role of science and technology to sustainable national development that it forms an integral part of the curriculum in school programmes (Umeoduagu, 2000). For instance, the Nigerian government came up with a policy that 60% of the students seeking admission into the nation's universities, polytechnics and colleges of education should be admitted for science-oriented courses, while 40% of the students should be considered for arts and social science courses. The National Policy on Education (Federal Ministry of Education [FME], 2013) states that the goals of science education in Nigeria should be to produce scientists for national development; and to service studies in technology and the course of technological development. In further pursuance of these goals the federal government, emphasized what other things the government should put in place to boost the teaching and learning of science, such as, establishing more universities of technology and special science schools at the secondary school level, the implementation of the 'Step B' project review of science curricular materials and texts through the instrumentality of the Nigerian Educational Development and Research Council (NERDC) and the Science Teachers' Association of Nigeria, respectively.

Despite the efforts of the government to reposition the teaching and learning of science, evidence from available literate shows that students achieve poorly in science subjects at all levels of education. The West African Examinations Council (WAEC, 2011) reports revealed that more than 40.00% of the students who wrote the examinations passed at below credit level in science subjects. The scenario is not different from the situation at the basic level of education. For instance, the Junior Secondary Certificate Examinations (JSCE) results in Kanam Local Government Area conducted by the Plateau State Ministry of Education showed that 71.00% of the students who sat for the Junior Secondary School Certificate Basic Science JSCE between 2011-2013 scored below credit level. This is not a good omen for a nation that is aspiring for sustainable national development.

Many researchers and scholars have blamed this sordid situation on the teaching method and competence of teachers (Ozoji, 2010; James, 2015). Experience as a basic science teacher shows that most science teachers in secondary schools in Kanam Local Government Area do not expose students to activity-oriented and problem-solving strategies of learning science, such as the use of thinking maps. This is because the teachers themselves are ignorant of the application and benefits of these effective teaching/learning methods on students' achievement in Basic science and technology. This study therefore investigated the effects of thinking maps on students' achievement and attitudes towards Basic science in Kanam Local Government Area of Plateau State.

Literature is replete with evidences of ineffective teaching and use of stereotyped and poor teaching methods in science classrooms as being critical in poor achievement of students in the sciences (Ozoji, 2010; Usman, 2015). Such methods are ineffective, not learner-centered and stifle meaningful learning and understanding of science and technology concepts and principles. There is therefore, the need for more activity-based innovative and learner-centered methods of teaching for effective science delivery. Such methods include: questioning-answering method, problem solving method and thinking mapping strategy.

Thinking maps are a useful tool for helping younger students with the process of building conceptual understanding of content and promoting achievement. By using thinking maps instead of traditional methods of teaching, students are able to visualize links between non-linear ideas, which in turn provides for creativity and meaningful learning. The use of colour is often used to differentiate ideas contained within the thinking map, which enhances the utility and meaningfulness of the maps to learners who construct them (Mona & Khalick, 2008). Thinking maps are essentially the visual representation of students' thought, as such, they allow for a greater retention of information by students. One of the most important aspects of thinking maps is the ability of students to display critical thinking skills in the course of completing their maps. In this study on the improvement of critical thinking skills, Savich (2009) noted that the foci on critical and independent thinking were effective ways for teachers to maximize the engagement of students in his class (Savich, 2009). Savich concluded that this inquiry method of teaching allowed even the least confident students in his class to feel connected to the material, which in turn allowed them to see the bigger picture of history (Savich, 2009). In the same manner, thinking maps allow students to feel more connected to the material, as it forces them to map out their thought processes on paper, which leads to an increase in connections between content and experience.

One of the proponents of the mind mapping, Hyerle (2000) maintained that brainstorming, organizers, and process maps were integral to building conceptual links in students' understanding and recollection. When these three qualities are applied to thinking mapping, they allow students to visualize their own thought process, in addition to making the construction of knowledge personal to them. However, thinking maps were unique in the sense that they force students to construct new knowledge about a topic while simultaneously recalling what they already knew. The use of thinking maps have been proved to increase the retention ability of learners when target information is visualized (Mona & Khalick, 2008). Moreover, Adegoke (2015) posits that if students are offered control over their map constructions, the maps have a positive impact on their achievement in sciences because they embody metacognitive models with certain structures. However, the use of thinking maps has its limitations, such as, the difficulty encountered in constructing maps by some students. Nevertheless, the advantages of thinking mapping instructional strategy outweigh its disadvantages. It is against the fore-going background that this study investigated the use of thinking maps as benchmarking tools for effective basic science instruction and the implications for sustainable national development.

Purpose of the Study

The purpose of the study was to determine the effects of thinking maps on students' achievement in Basic Science and technology in Kanam Local Government Area of Plateau State. The specific objectives of the study were as follows, to:

1. Find out the Basic science and technology achievement pre-test and post-test mean scores of JSS 2 students in experimental and control groups.

2. Determine the difference between the Basic Science and technology achievement post-test mean scores of students in the experimental group in urban and rural schools.

Research Questions

The following research questions were answered:

1. What are the basic science and technology achievement pre-test and post-test mean scores of students in the experimental group exposed to thinking maps and those in the control group not exposed?
2. What are the basic science achievement post-test mean scores of JSS students exposed to the use of thinking maps in urban and rural schools?

Null Hypotheses

The following null hypotheses were tested at 0.05 level of significance:

1. There is no significant difference between the post-test Basic Science Achievement Test mean scores of JSS 2 students in the experimental and control groups.
2. There is no significant difference between the post-test Basic science and technology Achievement mean scores of JSS 2 students exposed to thinking maps in rural and urban schools.

Methodology

The study employed the pre-test-post-test non-equivalent control group design. There are two groups in this design which are not composed on the basis of randomization but with intact groups (Awotunde, Ugodulunwa & Ozoji, 1997). The population for this study was made up of 1,210 JSS 2 students in 18 public junior secondary schools in Kanam Local Government Area of Plateau State. The sample for this study consisted of 120 students in two junior secondary schools in Kanam Local Government Area, with one school situated in a rural area while the other was situated in an urban area. In each school two arms of JSS 2 students were used, one arm as the experimental group and the other as the control group.

The study employed the non-randomized pre-test-post-test non-equivalent control group design. The instrument used for data collection was a Basic Science Achievement Test (BSAT) developed by the researcher. The BSAT was a structured multiple choice instrument. It comprised thirty multiple choice items. The questions covered the topics taught, namely, cellular respiration, living and non-living components of the environment, forms of energy and the importance of energy. Section A consisted of personal data of the students and Section B contained multiple choice items, true or false, and fill in the blanks. The Basic Science Achievement Test was constructed by the researcher using the National Curriculum for Basic Science and Basic science textbook. To ensure that relevant questions were set based on the cognitive objectives advanced by Bloom (1956), a table of specifications was used to set questions at the levels of recall, compression and evaluation.

The items were drawn based on three out of the six cognitive levels of Bloom's Taxonomy of Educational objectives, namely, knowledge, comprehension and application levels. The content validity of the BSAT was determined by subjecting it to the scrutiny of two experts in Science education and an expert in test and measurement, all in the Faculty of Education, University of Jos, Nigeria, for comprehensiveness and relevance of the items in line with the table of specifications constructed by the researcher. The reliability index was calculated as 0.93 using the Cronbach alpha method.

Procedure for Data Collection

Training of Research Assistants

Four research assistants who were Basic Science teachers in the schools used in the study were coordinated for the purpose of this research. The teachers had either an N.C.E or B.Sc. (Ed.) in basic science and with 3 to 5 year experience in junior secondary schools. However, only two teachers were used for the experimental groups and they were given a three-day training and orientation on the use of thinking Maps in teaching basic science concepts used in the study while the other two teachers that were used for the control group were not given any training on the use of thinking maps.

Administration of Pre-test

A pre-test was administered on the sample before the commencement of the teaching of the experimental and control groups.

Administration of Treatment to the Experimental Group:

The experimental group was taught the concept of photosynthesis, cellular respiration and forms of energy by trained research assistants in the schools used for the study, using thinking maps. The lesson notes prepared by the researcher were used for the teaching exercise. The circle thinking map was used for teaching photosynthesis, the multi-flow thinking map for teaching cellular respiration and the tree thinking map was used for teaching forms of energy. The treatment lasted for six weeks during which the students constructed the maps for on the said topics.

Teaching of the Control Group

The research assistants taught the control groups by teaching them with the conventional lecture method. The lesson notes already prepared by the researcher were used by the teachers to teach. The teaching lasted for a period of six weeks covering the topics: photosynthesis, cellular respiration and forms of energy from JSS 2 Basic science course textbook two.

Administration of Post-tests

The BSAT post-test was administered after the completion of the teaching exercise to both groups.

Method of Data Analysis

Descriptive and inferential statistics were employed in analyzing the data for the study. Means and standard deviations were used to answer the research questions while the t-test statistic was used to test the hypotheses at 0. 05 level of significance.

Results

Research Question One: What are post-test achievement mean scores of the experimental and control groups in Basic Science Achievement Test (BSAT)?

Table 1: Basic Science Achievement Test (BSAT) Post-test Mean Scores of Experimental and Control Group

Group	No.	Pre-test Mean	Post-test Mean	Mean Gain
Experimental	60	41.27	67.18	23.88
Control	60	39.00	43.30	

Table 1 shows that the BSAT post-test mean scores of the experimental and control groups were 67.18 and 43.30, respectively. This result shows a mean gain of 23.88 which indicates that thinking mapping strategy of instruction led to an improvement in students' achievement post-test mean score in Basic Science Achievement Test.

Research Question Two: What are the post-test achievement mean scores of JSS 2 students exposed to the use of thinking maps in Urban and Rural Schools?

Table 2: Basic Science Achievement Post-test Mean Scores of JSS Two Students exposed to the use of Thinking Maps in Urban and Rural Schools

Location	No. of Students	Mean	SD	Mean Gain
Urban	30	67.87	7.42	11.37
Rural	30	56.50	8.44	

Table 2 shows that the BSAT post-test mean scores of the JSS 2 students exposed to the use of thinking map were 67.87 and 56.50 respectively. This result indicates that school location did influence students' achievement when exposed to thinking maps strategy of instruction in Basic Science.

Null Hypothesis One: There is no significant difference between the post-test Basic Science Achievement Test mean scores of JSS 2 students in the experimental and control groups

Table 3: Summary of t - Test on Post-test Basic Science Achievement Test (BSAT) Mean Scores of Experimental and Control Groups.

Groups	N	$\bar{X}$	SD	df	t. cal	t. crit.
Experimental	60	67.18	7.91	118	15.10	1.66
Control	60	43.30	9.36			

$P < 0.05$

Data on Table 3 show that the calculated value of t (15.10) is greater than the critical value t (1.66) at df 118 and 0.05 level of significance. The null hypothesis was therefore rejected. The conclusion is that there was a significant difference between the Post-test Basic Science achievements mean scores of students exposed (experimental group) to thinking mapping strategy and students not exposed to thinking maps strategies (control group).

Null Hypothesis Two: There is no significant difference between the post-test Basic Science Achievement Test (BSAT) mean scores of JSS 2 students in the experimental exposed to thinking mapping strategy in urban and rural schools.

Table 4: Summary of t-test on Post-test Basic Science Achievement Test (BSATT) Mean Scores of JSS 2 Students in the Urban and Rural Schools Exposed Thinking Map Strategy.

Location	N	$\bar{X}$	SD	Df	t. cal	t. crit.
Urban	30	67.87	7.42	58	5.54	1.66
Rural	30	56.50	8.44			

$P \leq 0.05$

Data on Table 4 show that the calculated value of t (5.54) is greater than the tabulated value of t (1.66) at 0.05 level of significance. The hypothesis was therefore rejected. It was concluded that there was a significant difference between the post-test Basic Science Achievement Test (BSATT) mean scores of JSS 2 students in the experimental group exposed to thinking mapping strategy in urban and rural schools.

Discussion of the Findings

The results of the study showed that thinking mapping strategy as a means of instruction led to an improvement in students' achievement in basic science and technology. School location was also shown to affect students' achievement when thinking maps were used to teach. Table 1 shows that the BSATT post-test mean scores of the experimental and control groups were 67.18 and 43.30, respectively. This result indicates that thinking mapping strategy led to the improvement in students' achievement scores in Basic Science and technology Achievement Test. This finding is in agreement with the finding of Asan (2007) which showed that concept mapping had a noticeable impact on students' achievement in science classes.

Table 2 shows that the BSATT post-test mean scores of the JSS 2 students exposed to the use of thinking maps in urban and rural areas were 67.87 and 56.50, respectively. This result indicates that school location had a positive influence on students' achievement when exposed to thinking mapping strategy in Basic Science and technology. This finding is at variance with those of Igwebuike (2013) Agbaje and Awodun (2014) who discovered that school location did not influence students' achievement in science. Again, the finding showed that the use of thinking maps as a teaching/learning package had a differential impact on concept formation among students in urban and rural schools.

The data in Table 3 show that the calculated value of t (15.10) is greater than the critical value of t (1.66) at 118 degree of freedom and 0.05 level of significance. The null hypothesis was therefore rejected. The conclusion is that there was a significant difference between the post-test Basic science achievements mean scores of students exposed to thinking maps strategy and students not exposed to the strategy.

The data on Table 4 show that the calculated value of t (5.54) is greater than the critical value t (1.66) at 58 degree of freedom and 0.05 level of significance. The null hypothesis was therefore rejected. The conclusion is that there was a significant difference between the Basic Science and technology achievement mean scores of JSS 2 students in urban and rural schools exposed to thinking map strategies.

Implications of the Findings for Sustainable Development

The findings of this study have far reaching implications for sustainable national development because science and technology education is critical and contributes significantly and directly to sustainable development. This is because it lays the foundation for new approaches and technologies for tackling global challenges for the future of any nation. This may be why the United Nations Science Advisory Board (SAB, 2014) recommended the international community to integrate science into the post-2015 development agenda including Sustainable Development Goals.

Students should as a matter of urgency be taught science and technology concepts and principles with activity-oriented, learner-centered, hands-on and minds-on strategies, such as the use of thinking maps for in-depth understanding and meaningful learning of science and technology concepts and principles, as well as good achievement outcomes. The findings of the study showed that engaging students in the use of thinking maps in basic science and technology classrooms has the capacity to expand their critical thinking skills and science/technology processes. Critical thinking skills brought about by science and technology education is fundamental in training the mind, understanding the world, creating change, making choices and taking decisions that affect nations, as well as, solving every day problems that stare human beings in the face, such, as hunger and poverty, climate change, terrorism and war, etc.

To make the most of the transforming power of science and technology education, it has to commence at the basic level both in urban and rural areas with innovative and effective strategies, such as, thinking mapping strategy as benchmarking tools. It is disheartening that the national curriculum for basic science and technology emphasizes the use of activity-based approaches in teaching the subject but what basic science and technology teachers do from experience in the name of teaching is the reverse. This calls not only for the training and retraining of teachers in innovative teaching techniques but for a change of attitudes by science and technology teachers from the manner in which teaching is done presently, particularly, at the basic level of education and in rural areas in the country.

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