COMPUTER-BASED CONCEPT MAPPING: A COGNITIVE TOOL FOR ENHANCING ACADEMIC PERFORMANCE AMONG SECONDARY SCHOOL BIOLOGY STUDENTS IN ZARIA, NIGERIA.

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Abstract

This study investigated Computer-Based Concept Mapping (CBCM) as a tool in the field of science education to help students in understanding basic concepts and relationships between them. It was carried out in Zaria Educational Zone. The study employed quasi-experimental design without control group. A sample of one hundred and twenty-five Senior Secondary Two (SSII) students from intact classes in three co-educational schools was drawn from the population of six thousand and eighty-one students. The sample comprised of fifty-three males and seventy-two females. The three experimental groups were taught Human Circulatory system for a period of six weeks. using Construct-on-Scaffold, Construct-by-Self and Paper-and-Pencil strategies respectively. The instruments used for data collection were "Circulatory System Concept-Mapping Tests". Instruments were validated by experts. Cohen's Kappa was used to calculate Inter-Rater Reliability (IRR) for scoring the Construct-on-Scaffold, Construct-by-Self and Paper-and-Pencil concept-mapping tests to be 0.80, 0.60 and 0.70 respectively. Means, standard deviations, Analysis of Variance, Tukey's and Z-test statistics were tested at $P \leq 0.05$. Results showed that the Impact of the three Concept-mapping strategies on the performance of students in Biology was significant ($P=0.003<0.05$). Students in COS Strategy performed better than CBS and PAP strategies. Male and female students in the CBCM strategies did not differ significantly in their mean rubric scores ($P=0.14> 0.05$). Based on these findings, it was recommended that Biology teachers should adopt the Construct-on-Scaffold Concept-Mapping Strategy as a useful tool for teaching students how to construct their own concept maps.

Keywords: Computer-Based, Concept-Mapping, Academic Performance, Biology, Secondary School, Students.

Introduction

Quality education is considered to be one of the key elements of sustainable development in the world. In contemporary Nigeria, greater emphasis is placed on science and technological development. The domain of science is exceptionally critical to the prosperity of Nigeria in the 21st century (Okebukola, 2015) The American Association for the Advancement of Science, (AAAS, 2010) argues that an understanding of Science concepts and principles is crucial to developing Scientific literacy and also for meaningful and productive careers in Science.Science and technology subjects are taught in schools all over Nigeria and any nation that hopes to develop must not neglect teaching such subjects in its school (FRN, 2013). One of such subjects is biology. Okebukola (2015) observed that the method of teaching biology and the curriculum that is used in Nigeria is defective and not in the tune with modern trends of teaching. The National Science Education Standards (NRC, 2010) also asserts that what students learn is greatly influenced by how they are taught.

The ever-increasing diversity in today's classrooms is prompting teachers to incorporate a multidimensional approach to lesson delivery. The classroom in the 21st century is also more focused on a proactive learning environment rather than merely dispensing information. Hence, it is vital that teachers offer a rich and varied pedagogy to accommodate the diverse 21st century classroom (Veira, 2015). As the use of technologies in classroom matures it is necessary to examine how technology can enhance learning effectively and add to the quality of education. Cognitive tools that actively engage learners in creating knowledge and reflects their comprehension, conceptualization of information and ideas should be adopted rather than absorbing predetermined presentations of objective knowledge (Adesope& Nesbit, 2013; Adesope, Cavagnetto, Hunsu, Anguiano & Lloyd, 2017). Concept maps is one of such cognitive tools.

A concept map is defined as a hierarchical, graphical display of text material in a two-dimensional, spatial, node-link network (Novak, 2013). Novak and his associates developed concept-mapping in the 1970s as a strategy to support meaningful learning for students in the classroom by providing visual framework on which to build new information upon existing knowledge. Novak states that meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures. In concept-mapping, hierarchical relationship among concepts and propositions is constructed graphically and this actively engage students in their own meaningful learning process. By viewing learning as an active process, taking students prior knowledge into consideration, building on preconceptions and eliciting cognitive conflicts graphically, teachers can design instruction that explores reasoning abilities of learners for organizing information about science concepts to facilitate meaningful learning and is more likely to lead to deeper and longer lasting understanding. The underlying theory which underpins concept mapping is the Ausubel's assimilation cognitive learning theory which is based on meaningful learning. Ausubel (2000) advocated for the use of advance organizers which should be designed to provide mental scaffolding to learning. He proposed that new information is incorporated into the existing knowledge base which provides for better understanding and longer retention of subject matter by the student. Concept-mapping strategy was developed by Novak in 1970s.

Technology can be employed to enhance the skills acquisition process, improve critical thinking, engagement and empower individuals to seize opportunities and exploit their potentials (Visvizi, Lytras& Daniela, 2018). Initially Paper-and-Pencil based concept maps were extensively used for learning and instruction, however, Computer-based or online resources are now widely available and are now used to construct concept maps. For efficient use of Concept maps in education, technology-based Concept-mapping systems have been developed (Chang, Yao-Ting, Rey-Bin &Shui-Cheng, 2005; Sıksoy, 2019). The students of the 21st century are technology savvy and are able to learn, work and play as mobile computing devices are omnipresent (Bolstad, 2011). Competency-based learning combined with innovative learning methods that make use of technologies and inquiry-problem-based approaches (e.g. Computer-Based Concept Mapping Strategy) will help learners to develop 'higher-order thinking skills (Saavedra &Opfer, 2012).

The Computer-Based Concept Mapping (CBCM) is an important tool that is used in the field of education to help students in understanding the basic concepts and the relationships between them and has the potential to enhance meaningful learning in education (Arruarte, Elorriaga, Calvo, Larrañaga& Rueda, 2012). With CBCM, concept representations and their respective links are not static. Both can be expanded as knowledge or elaboration of an idea increases. Errors in describing an idea can be easily corrected and adapted. Most computer assisted concept mapping tools allow the user to point and drag a concept or group of concepts to another place on the map and automatically update all the appropriate links (Hwang, Kuo, Chen & Ho, 2014). The software usually allows the user to change his/her map to different electronic formats (e.g. from outline to graphic). These electronic formats can then be stored, sent, manipulated, used, printed and deleted just like any computer file. Concept map in digital format can be easily sent as attached files with e-mail messages, included in a web page or documents and can also facilitate cooperative tasks. By applying concept mapping software as a supplementary tool, teachers can plan more effective lessons, have better insight into students' thinking processes, better understand students' difficulties and provide timely remedial instruction (Chang, Liu, Chen, Huang, Lai &Yeh, 2017).Using the computer to create concept maps has practical advantages. There is an ease of construction, revision and the ability to customize maps in ways that are not possible when using paper and pencil (Wu, Hwang, Milrad, Ke& Huang, 2012). Sıksoy (2019) also highlighted Some advantages of technology-based concept mapping. These includes: easy restructuring, highlighting, commenting, presentability, manipulation, dynamic linking, conversion and storage. Over the last decade, a number of products have emerged to support computer- based concept mapping. These include SemNet, Learning Tool, Inspiration, Bubbl.us, MindMup, Free Mind, Mindomo, MindMaple, XMind, Virtual Understanding Environment (VUE), CMapTools and Prezi (Vural, 2010). Two CBCM strategies: Construct-on Scaffold (COS) and Construct-by-Self (CBS) which were developed with the CMapTools software and Paper-and-Pencil (PAP) Concept-mapping strategy were adopted in this study.

Canas and Novak (2012) advocated the use of expert generated skeleton concept maps to serve as scaffold to learning, providing parking lot for the students by the teacher and the use of CMap Tools software for graphic construction of the maps. The Construct-on-Scaffold (COS) maps are fill-in-the-maps in which concepts or linking words were intentionally omitted from an Expert/Teacher Generated concept map. An expert generated concept map is one that has been created by one or more experts to present the content to be learned (Canas& Novak, 2012). The content is organized according to the structural view of the experts. This concept map is then subsequently used as a resource by the learners as a means of exploring and mastering the educational material. Novak (2010) reported that Expert Generated maps are more accurate representations of the nature and organization of information than Teacher/Student Generated maps and it reduces the possibility that students may process information in a random or haphazard way. The expert map is used as a kind of scaffold that helps learners to attain higher levels of performance. The principles of scaffolding instruction and completion strategy by Van-Merrienboer (1990) and Paas (1992) were used to modify the way concept-mapping was used in fill-in-maps strategies.

The Construct-by-Self (CBS) strategy enables students to freely construct their maps with computer but without scaffolding aid. Any Concept mapping software can be installed into the computer systems for students use to construct maps. Both Construct-on Scaffold and Construct-by-Self are computer-based concept mapping strategies. In Paper-and-Pencil strategy, students are enabled to construct Concept maps freely but without both scaffolding aid and computer. Chang, Sung and Chen (2001) noted that constructing concept maps using paper and pencil has some obvious disadvantages: not easy for a teacher to provide appropriate feedback to students during concept mapping, concept map is complex and difficult for students to construct and revise. Because of these difficulties involved in 'Paper-and-Pencil' concept mapping, researchers built computer-based concept mapping systems to help students construct concept maps more easily.

Although there are several studies that emphasize the benefits of using concept mapping as a tool in the process of teaching, there is limited number of studies on the use of Computer-based Concept-mapping as a teaching strategy (Gijlers& de-Jong, 2013; Hwang, Kuo, Chen & Ho, 2014; Sıksoy, 2019). Furthermore, to provide secondary school biology students with opportunities for meaningful learning to occur in the educational system is a challenge to all teachers.

This research tried to determine the effect of two CBCM Concept-mapping strategies and one other Concept-mapping strategy (Construct-on-Scaffold, Construct-by-Self and Paper-and-Pencil respectively) on Senior Secondary School Biology Students Academic Performance in Zaria Education Zone.

Persistent poor performance of students in Biology at Senior Secondary Examinations in Kaduna State schools could be attributed to the teaching methods popularly used by their teachers for the teaching and learning of Biology. Literatures have advocated the use of active learning and innovative student-centered strategies for teaching. Since the introduction of concept mapping by Novak in the 1970s, research indicates that concept mapping is an effective strategy that leads to meaningful learning. These researches has been conducted for more than a decade but unfortunately, integrating the use of concept mapping into the science curriculum is not without problems. These problems have prevented the learning strategy from having had a more profound impact on the quality of science instruction. These highlights the need for further researches to investigate the various concept-mapping strategies so that students can utilize learning strategies that are the most useful and can result to meaningful learning. Majority of the previously conducted concept-mapping researches does not include evaluation of the concept maps produced by students. Scoring the concept maps in this study will further enable the researcher to know if the students have learnt the concept-mapping activities meaningfully. In addition, there are little or no studies on the use of CBCM concept-mapping strategies to determine academic performance among biology learners at secondary school level in Nigeria.

[The objectives of this Study were to:

- determine the effect of the three Concept-mapping Strategies (Construct-on-Scaffold, Construct-by-Self & Paper-and-Pencil) on rubric scores obtained in Concept-Mapping among Senior Secondary School Biology Students.
- determine gender disparity among Senior Secondary School Biology Students taught with Computer-Based (Construct-on-Scaffold & Construct-by-Self) Concept-Mapping Strategies.

The following research questions and hypothesis postulated at P≤ 0.05 were posited to guide the conduct of the study:

- What is the difference in the rubric scores obtained by Secondary School Biology students taught with Construct-on-Scaffold, Construct-by-Self and Paper-and-Pencil Concept-Mapping Strategies?
- Will there be any gender difference in the rubric scores of Senior Secondary School Biology students taught with Computer-Based (Construct-on-Scaffold & Construct-by-Self) Concept Mapping Strategies?
- There is no significant difference in the mean rubric scores obtained by Secondary School Biology students taught with Construct-on-Scaffold, Construct-by-Self and Paper-and-Pencil Concept-Mapping Strategies.
- There is no significant difference in the rubric scores obtained by Male and Female Secondary School Biology students taught with Computer-Based (Construct-on-Scaffold &Construct-by-Self) Concept-Mapping Strategies

Method

The design for this study was Quasi-experimental. The population of the study involved all SS II Biology students of twenty-seven public Senior Secondary Schools in Zaria Education Zone (6081) with average age range of 17 years as at 2017. Three co-educational schools were randomly selected by balloting. Because of the nature of the experiment, three intact classes were also randomly selected from the three schools to serve as experimental groups. Sample selected for the study is 125 students which consists of Construct-on-Scaffold Group (COS- 42 students), Construct-by-self Group (CBS- 35 students) and Paper-and-Pencil Group (PAP- 48 students) respectively. Sample comprised of fifty-three males and seventy-two females. The instrument used for data collection is: Circulatory System Concept-Mapping Tests (CSCMT). Four Science Education experts with PhD from Ahmadu Bello University, Zaria validated the instruments for this study. A pilot study was done to determine the inter-rater reliability of scoring the concept-maps. The researcher and one of the experienced Secondary School Biology teachers, from one of the sampled schools scored six concept maps together (two of each type) to calibrate the scoring. All maps created by the subjects were evaluated using a scoring instrument created by Lomask, Baron, Greig and Harrison (1992). Subsequently, each scorer individually scored five of the same Construct-on-Scaffold, Construct-by-Self and Paper-and-Pencil concept maps. Cohen's Kappa was used to calculate Inter-Rater Reliability (IRR) to be 0.80 for Construct-on-Scaffold, 0.60 for Construct-by-Self and 0.70 for Paper-and-Pencil maps.

The study began with the administration of Circulatory System Performance Test (CSPT) as pretest which indicate a no significant difference in mean values of students in three groups, then training of all participants for one week (two hours each day) of their respective Construct-on-Scaffold, Construct-by-Self and Paper-and-Pencil concept-mapping strategies by the researcher. The training includes an introduction to concept mapping, guided practice, independent practice and feedback on the concept maps. COS and CBS groups were trained and taught with computers at a nearby Computer Centre due to lack of adequate computers in the sampled schools. Expert maps (Scaffolds) adapted from Dosanjh (2011) were installed in the computer system and a parking lot (a list of concepts and propositions) was provided per lesson for COS group, CmapTool software was downloaded and installed on the computers and a parking lot was also provided per lesson for CBS group while PAP group were given only parking lots per lesson to construct their concept maps with Paper and Pencil. Treatment was done by teaching the circulatory system topic by the researcher and students constructed their respective concept maps for six weeks in all sampled schools. Concept maps were scored and feedback was always given to students at the end of every lesson. Data was collected by administering the fill-in-map CSCMT (adapted from Dosanjh, 2011) for COS students while students in CAS and PAP students constructed their maps at the end of the study. Frequency, mean, standard deviation, z-test, ANOVA and Tukey's test were used for analysis of data using SPSS version 22.

Result

Table 1: Mean Rubric Scores of Biology Students taught with Construct-on-Scaffold, Construct-by-Self and Paper-and-Pencil Concept-Mapping Strategies

Groups	N	$\bar{X}$	S.D	Mean Difference
Construct-on-Scaffold	42	2.74	0.83	0.25
Construct-by-Self	35	2.49	0.74	
Construct-on-Scaffold	42	2.74	0.83	0.55
Paper and Pencil	48	2.19	0.67	
Construct-by-Self	35	2.49	0.74	0.30
Paper and Pencil	48	2.19	0.67	

Table 1 shows that there is a difference in mean rubric scores between students taught biology using Construct-and-Scaffold and Construct-by-Self Concept-mapping strategies with a mean difference of 0.25 in favour of those taught using Construct-on-Scaffold teaching strategy. Similarly, in comparing the mean rubric scores of biology students taught using Construct-on-Scaffold with biology students taught using Paper and Pencil strategy, a mean difference of 0.55 was recorded in favour of students taught using Construct-on-Scaffold while Construct-by-self and Paper and Pencil strategies had a mean difference of 0.30. This implies that teaching using Construct-on-Scaffold has more positive impact on students' academic performance. The significance of the mean differences was tested in the related hypothesis.

Table 2: Summary of ANOVA for Mean Rubric Scores of Secondary School Biology Students taught with Construct-on-Scaffold, Construct-by-Self and Paper-and-Pencil Concept-mapping Strategies

	Sum of Squares	df	Mean Square	F	P	Remark
Between Groups	6.83	2	3.42			
Within Groups	68.17	122	0.56	6.11	0.003	Significant
Total	75.01	124				

***Significant at P≤ 0.05 level**

Results presented in Table 2 reveals that the effect of treatment on secondary school Biology students' performance is statistically significant (*P* = 0.003 < 0.05). The null hypothesis which states that there is no significant difference in the mean rubric scores obtained by Secondary School Biology students taught with Construct-on-Scaffold, Construct-by-Self and Paper-and-Pencil Concept-mapping strategies is therefore rejected. This implies that teaching biology using Concept-on-Scaffold, Concept-by-Self and Paper and Pencil strategies significantly affect the performance of secondary school Biology students. Tukey post-hoc test was carried out in order to determine the strategy that had more significant impact on students' performance in concept-mapping. Result is presented in Table 3.

Table 3: Tukey Post-hoc Test for Mean Rubric Scores of Students Taught Biology Using the Three Concept-Mapping Strategies

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	p. value	Remark
Construct-on-Scaffold	Construct-by-Self	0.25	0.17	0.31	N.S
	Paper and Pencil	0.55*	0.16	0.00	S
Construct-by-Self	Construct on Scaffold	-0.25	0.17	0.31	N.S
	Paper and Pencil	0.30	0.17	0.18	N.S
Paper and Pencil	Construct-on-Scaffold	-0.55*	0.16	0.00	S
	Construct-by-Self	-0.30	0.17	0.18	N.S

***Significant at P≤0.05**

Results of Tukey post hoc test in Table 3 revealed that there is a statistically significant difference in rubric scores between secondary school Biology students taught with Construct-on-Scaffold and Paper and Pencil strategies and vice-versa. The p-value of 0.00 is less than 0.05 level of significance which implies that a significant difference exists between them in favour of Construct-on-Scaffold strategy. However, there was no difference between the secondary school biology students taught when comparing Construct-on-Scaffold and Construct-by-Self strategies as well as Paper and Pencil and Construct-by-Self. This is because the p-values of 0.17 obtained is greater than 0.05 level of significance.

The rubric scores obtained by secondary school Biology students exposed to Computer-Based concept mapping strategies was analyzed descriptively using mean ranks and the mean rank difference as presented in Table 4.

Table 4: Summary of Mean Ranks for Mean Rubric Scores of Male and Female Students Exposed to Computer-Based Concept-mapping Strategies

Variable	Groups	N	Mean Rank	Sum of Ranks	Mean Rank Differences
Computer-Based Strategies	Male	32	43.16	1381.0	7.12
	Female	45	36.04	1622.0	
	Total	77			

The outcome of the Mean Rank statistic in Table 4 shows that difference exist between the rubric scores of male and female students exposed to Computer-based strategy. Their computed Mean Rank rubric scores are 43.16 and 36.04 for male and female students respectively with a difference of 7.12 in favour of male secondary school Biology students. In the same vein their computed Sum of Ranks are 1381.0 and 1622.0. Male students exposed to Computer-based strategy had higher rubric scores than their female counterparts. Significance of the difference was tested in the related hypothesis. To test null hypothesis two, the mean rubric scores of secondary school Biology students exposed to computer-based strategy by gender were subjected to Z-test. The result is shown in Table 5.

Table 5: Z-Test for Rubric Scores of Male and Female Students Exposed to Computer-Based Concept-Mapping Strategies

Variable	Gender	N	Mean Rank	Sum of Mean Ranks	Z	P	Remark
Computer-Based Strategies	Male	32	43.16	1381.0	-1.48	0.14	NS.
	Female	45	36.04	1622.0			

***Not Significant at $P \leq 0.05$**

The outcome of the Z-test in Table 5 shows that there is no significant difference between the mean rubric scores of male and female Secondary School Biology students exposed to Computer-Based Strategies. This is because the calculated P value of 0.14 is greater than the 0.05 alpha level of significance. Although male students exposed to Computer-Based Strategies had higher rubric scores than their female counterparts, the difference is not significant. Therefore, the null hypothesis which states that there is no significant difference in the rubric scores obtained by Male and Female

Secondary School Biology students taught with Computer-Based (Construct-on-Scaffold & Construct-by-Self) Concept-Mapping Strategies was retained implying that the computer-based Concept-Mapping Strategies are gender friendly.

Discussion

The study showed that the students differed significantly by the three different Concept-mapping strategies (P=0.003<0.05). This result supports Chang *et al*., (2001); Chang *et al*., (2017) and Siksoy (2019) who all reported a significant difference. The results in Table 3 showed that COS Strategy had more significant impact on rubric performance of the students in concept-mapping activities than the CBS and PAP. The significant value obtained 0.003 was below 0.05. Since significant value is less than P value, then there is significant difference. The result is also in line with Chang *et al.*, (2001), Chiou (2015) and Adesope*et al.*, (2017) that COS Strategy had higher impact on biology students performance in concept mapping activities than CBS and PAP. The fact that learning through a scaffold produced the best learning effects may result from the reduced workload provided by the scaffold aid. Paas (1992) suggested that to avoid a possible overload on students, Construct-on-Scaffold Strategy is a good way of presenting learning materials. Both CBCM strategies enhanced learning better than PAP. However, this result is contrary to Liu *et al.*, (2010) and Vural (2010) who discovered a no significant difference among the three strategies. Mean ranks in Table 4 showed a gender difference of 7.12 but Z-test results in Table 5 indicate a no significant gender difference between male and female students (P=0.14 > 0.05). This implies that the CBCM Strategies are gender friendly. This result supports Vural (2010) who also discovered a no significant difference between male and females taught with CBCM Strategies

Conclusion

For efficient use of concept maps in education, technology-based Concept-Mapping Strategies should be adopted. Using the computer to create concept maps no doubt has practical advantages. Students were able to construct with ease, revise and were also able to customize maps in ways that are not possible when using Paper and Pencil. CBCM strategies were more interesting to students for concept map construction and they also had fun while learning. The PAP strategy is a more complex and difficult way of constructing concept maps. Concept-Mapping might enhance cognitive learning after the basic skills are acquired and the learners become competent concept mappers.

Recommendation

The following recommendations are made on the basis of the outcomes of this study:

1. When using concept-mapping strategy, biology teachers should adopt the COS Mapping Strategy as a useful scaffold for teaching students how to construct their own concept maps.
2. Government should provide necessary facilities like computers, adequate electricity and financial support to enable biology teachers to effectively use the CBCM strategies.
3. Biology students should also adopt the COS learning strategy as this will enable them to understand better and aid them in constructing their own maps.
4. Assessment of concept maps with pre/posttests only is not adequate enough to indicate achievement. Biology teachers should endevour to use scoring rubrics for concept map assessment.
5. Government and other stakeholders should help to organize workshops to re-train teachers on the use of CBCM strategies to enhance learning.

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