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Research Article

Towards Enhancement of Student's Achievement in Physics Using Concept Mapping Strategy and Guided Discovery Method

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Abstract

This study investigated the relative effectiveness of Concept Mapping Strategy (CMS) and Guided Discovery Method (GDM) in enhancing student's achievement in Physics. Gender influence on student's achievement was also examined. A total of one hundred and fifteen (115) secondary school Physics students were involved in the study; the research work was carried out in the Wukari Education Zone of Taraba State. This research work adapted a quasi-experimental research design involving pre-test and post-test. Three research questions and three hypotheses were raised. Physics Achievement Test (PAT) was used for data collection. The items of PAT were subjected to item analysis. The reliability coefficient of the instrument was obtained using Kuder-Richardson 20 formula is .8. Mean and standard deviation was used to answer the research questions, while Analysis of Covariance was used to test the hypotheses formulated at .05 significance level. From the analysis, it is revealed that a statistically significant difference exists in the mean academic achievement scores of students taught physics using CMS and those taught using GDM in favor of CMS. Gender differences are not statistically significant in the mean academic achievement scores for both CMS and GDM groups. It is evident from the findings of this study that the use of CMS could provide a good way for students to learn Physics. It is recommended, based on the findings of the study, that Physics teachers should be encouraged to use a CMS while teaching Physics concepts to actively involve the students in identifying relationships in concepts. Government should utilize the services of various professional bodies like the Science Teachers Association of Nigeria (STAN) in collaboration with the Nigeria Educational Research and Development Centre (NERDC) to organize seminars, workshops, conferences, in-service training and symposia to inform and train physics teachers on the use of innovative teaching method especially concept-mapping.

Keywords: achievement in physics, concept mapping, guided discovery

Introduction

Science education is a mechanism for the economic, political, logical and scientific development of all nations. The vital role played by science in contemporary society is indispensable. In recognition of the important role of science for national development, the Federal Republic of Nigeria in the National Policy on Education (Federal Republic of Nigeria, 2018) gave a special place to science (Physics inclusive), technology and mathematics education and the promotion of scientific and technological literacy to her citizenry. Awodun (2015) opined that Physics is the most utilized basic science subject in most technology and technology-related profession. This simply indicates that the vast role that Physics plays in the technological growth of any nation must not be undermined. Physics is also a cross-cutting discipline that has applications in many sectors of economic development, including health, agriculture, energy and information technology (MacMillan, 2012; Murenzi, 2006). Indeed, the knowledge of Physics has led to so many inventions such as the production, application and utilization of integrated circuits, production and use of machines and other contrivances. Despite the immense contributions of Physics to society, Oni (2014) reported that student's achievement in Physics is not encouraging, as Nigeria has

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witnessed persistent poor student performance in Physics at the Secondary School Certificate level. The West African Examination Council (WAEC) Chief Examiner's Reports from 2009 to 2018 shows students deteriorating performances in Physics at the School Certificate Examination level. The Chief Examiner's reports indicated that lack of understanding of fundamental concepts of physics contributed to the poor performance of students in physics examinations. This has serious implications for national development, security, economy, and manpower for a country with a vision of becoming one of the leading nations in science and technology (Gambari & Yusuf, 2017). These awful performances and continual underachievement in Physics, if not checked, will continue to jeopardize the placement chances of science students in post-secondary institutions.

Student achievement has become the key factor for personal progress. The aspiration to ascend the step-ladder of achievement to a high rank places pressure on students, teachers, and school and, in general, the educational system. Achievement refers to how an individual is able to demonstrate his or her intellectual abilities successfully, especially using their own efforts and skills (Edokpayi & Suleiman, 2011). Achievement is the act of accomplishing an academic task productively. Bajon (2015) regarded achievement as a task that has been accomplished successfully, especially by means of exertion, skill practice, or perseverance. In science instructions, if a learner accomplishes a task successfully and attains the set objectives for a particular learning experience, the learner is said to have achieved his/her aims. The difficulty students experience in understanding physics concepts appears to cut across many countries (Nigeria inclusive), as can be seen from previous studies (Checkley, 2010; Obafemi & Onwioduokit, 2013; Ogunleye, 2013). Adegoke (2011) reported that students are not actively involved in developing knowledge; they receive information passively and are less motivated. The instructional method employed by the teacher plays an important role in the acquisition of skills and meaningful learning. In order to improve student's academic achievement, research into science teaching strategies such as Concept Mapping Strategy (CMS), Guided Discovery Method (GDM) and many others have been developed with the aim of making learning more meaningful and less complex.

Concept mapping has become a powerful tool that is frequently applied in a different context in science education (Auta, 2015). According to Samba and Eriba (2012), concept mapping is a process of making a concept map. The end product of the process is a pictorial representation, a graphical picture referred to as a concept map. Concept mapping is a powerful but simple way of using diagrams to show information in the same way one thinks. Concept mapping makes it easy to understand, remember, and communicate complex information. Concept Mapping, therefore, stands as an effective tool for problem-solving, inculcating creativity in the learner by creating a clearer view and valid communication to the problem at hand. Okuntola and Wahab (2011) asserted that concept mapping is very useful in the teaching and learning process for systematizing and organizing not only the concepts under study but also the already learned concepts. They believe it is used for building a new system for measuring our external world. The approach they concluded, if properly adopted, will: Promote better retention and understanding of the subject matter. Also, concept details are easily reconstructed from a map; this reduces the burden on memory and thus reduces memorization errors; shows the organizational structure of content as a compact source of information; It is a versatile teaching tool that can be used to present and reinforce content or assess its understanding. It supports students in making the connection between known information and new information; by creating maps, students clarify their understanding of the topic and integrate new ideas into their thinking and it aids students in summarizing texts and identifying main ideas as well as provide a useful way to assess student's understanding of a topic. Concept mapping has been adequately advocated in literature as strategies for meaningful learning of abstract concepts and assists learners in learning about conceptual changes (Jack & Suleiman, 2020). Several studies have found the use of concept mapping very effective in science teaching and learning difficult concepts in science (BouJaoude & Attieh, 2008; Karakuyu, 2010; Otor & Achor, 2013). The use of concept mapping strengthens a solid and precise understanding of the meanings and inter-relations of concepts.

The GDM involves helping the learner to discover certain facts or answers to a given problem. According to Garuma and Tesfaye (2012), the GDM is intentional discovery learning through problem-solving under the teacher's supervision. The GDM is a student-centered method in which the learner uses his mental process to mediate or find out things for himself; oftentimes, learners depend on their teachers to provide all the answers they need. The teacher provides the setting, the structure and the materials and guides students to discover answers to problems. In guided discovery, the answer to the problem is already known to the teacher, but he/she wants the learner to discover it. The teacher's role in guided discovery is to serve as the facilitator of learning in which students are encouraged to be responsible autonomous and construct their understanding of each concept (Olorode & Jimoh, 2016). The GDM increases the degree of student's interest, innovativeness, problem-solving ability, creativity and consequently improves their achievement in both theory and practice (Ozioko, 2015). Students should be given the opportunities to develop, interact, and find out solutions to problems themselves so that the cognitive and affective development of students in science can be improved irrespective of gender.

Gender has been advanced as one of such factors that may have a considerable effect on student's academic achievement, especially in science subjects such as Physics. Gender is the range of physical, biological, mental and behavioral characteristics pertaining to and differentiating between the feminine and masculine (female & male) population (Filgona, 2017). Some vocations and professions have been regarded as men's (engineering, medicine, & agriculture), while others as women's (catering & nursing). Hence, science-oriented subjects (Physics inclusive) in most cultures are defined as masculine. In a nutshell, what is regarded as complex and difficult tasks are allocated to boys, whereas girls are expected to handle the relatively easy and less demanding tasks. This difference in treatment through education created and sustained the gender gap, which also became visible in the science-related disciplines. Filgona (2016) and Nwona and Akogun (2015) noted imbalance against girls in science, technology and mathematics. Eravwoke (2011) reported that gender had no effect on the academic performance of students. However, the results of Odagboyi (2015) showed that there was a significant difference between student's achievements in favour of the males. These findings gave room for the inclusion of gender as a moderating variable for this study.

The study investigated the relative effectiveness of CMS and GDM in enhancing student's achievement in Physics. It also examined the achievement of male and female students in Physics when taught using the CMS as well as the GDM.

Statement of the Problem

Nigeria has witnessed persistent poor student's performance in Physics at the Secondary School Certificate (SSCE) level. The WAEC Chief Examiner's Reports from 2009 to 2018 shows students deteriorating performances in Physics at the School Certificate Examination level, indicating that lack of understanding of fundamental concepts of physics contributed to the alarming performance of students in physics examinations which possibly the effect of gender in the subject matter. In view of these appalling problems, the search for an appropriate alternative to teaching becomes of utmost importance, which has necessitated the need to introduce other teaching strategies that are student-centered such as the CMS and GDM, to find out whether these instructional strategies could control and limit underachievement in Physics irrespective of gender.

Research Questions

The following research questions raised guided the study:

1. What is the difference in the mean academic achievement scores of students in Physics taught using Concept Mapping and those taught using the GDM?
2. What is the difference in mean academic achievement scores of male and female students in Physics taught using Concept Mapping instructional strategy?
3. What is the difference in mean academic achievement scores of male and female students in Physics taught using the GDM?

Hypotheses

The hypotheses postulated for the study, tested at .05 level of significance, includes:
Hypothesis 1: There is no statistically significant difference in the mean academic achievement scores of students taught physics using CMS and those taught using the GDM.
Hypothesis 2: There is no statistically significant difference in the mean academic achievement scores of male and female students taught physics using the CMS.
Hypothesis 3: There is no statistically significant difference in the mean academic achievement scores of male and female students taught physics using the GDM.

Methodology

The study adopted a quasi-experimental design. Specifically, the pre-test and post-test; non-equivalent, non-randomized group design was used. Two experimental groups were used because it is a comparative study that aimed at comparing the effectiveness of the two learning strategies, which are learner-centered, to determine which strategy is more effective in the learning of physics. The population for the study consisted of 1,730 Physics students, made up of 727 females and 1003 males. The sample size comprises 115 Physics students, consisting of 73 males and 42 females drawn from two public science-oriented secondary schools using multistage sampling techniques. Physics Achievement Test (PAT) was the instrument used for data collection. Physics. PAT contains 50 multiple choice objective items. These questions were drawn from the past West African Senior School Certificate Examination (WASSCE) question papers, which are based on the curriculum content for SS2 Physics to test the student's knowledge, comprehension, and application of selected topics in Physics as reported by the WAEC Chief Examiner's Reports which includes Sound wave and Molecular theory of matter. Each question was made up of five (5) options A to E. PAT was validated for face and content by two experts in the Department of Science Education and one from Measurement and Evaluation, all from the Faculty of Education, Taraba State University, Jalingo. Their remarks and comments suggested that an upgrade should be made on the 40-items to 50-items, five (5) letter options A-E be made. Based on the comments and suggestions of the experts, corrections and modifications were made to the final instrument.

An intact class of forty (44) SS II students was used for the pilot testing. The instruments PAT was administered to the students. The result obtained from the administration of PAT was used to calculate its reliability coefficient. PAT was found to have a reliability coefficient of .82 using the Kuder Richardson formula 20 (K-R20). Research questions were answered using the descriptive statistic of the mean and standard deviation of the scores to compare the means of the groups and the deviation of these scores. The hypotheses were tested at .05 level of significance using the inferential statistics of analysis of covariance (ANCOVA) with the pre-test serving as covariates.

Results

Research question 1: What is the difference in the mean academic achievement scores of students in physics taught using concept mapping and those taught using the GDM?

Table 1
Mean Achievement Scores and Standard Deviations of Students Taught Using CMS and those Taught Using GDM

Group	*N*	Pre-test mean	*SD*	Post-test mean	*SD*	Mean gain
CMS	59	16.73	2.85	32.78	4.31	16.05
GDM	56	16.27	2.32	23.39	4.48	7.12
Difference		.46		9.39		8.93

Table 1 shows that the post-test mean score of students taught using CMS is 32.78 with a standard deviation of 4.31, while those taught using GDM have a mean score of 23.39 with a standard deviation of 4.48. The difference between the pre-test and post-test mean scores of the CMS group is 16.05, while that of the GDM group is 7.12. The pre-test and post-test achievement mean score differences for the two groups show that the CMS group is higher. The implication is that the students who taught Physics with CMS gained in achievement more than their GDM counterparts.

Research question 2: What is the difference in mean academic achievement scores of male and female students in physics taught using concept mapping instructional strategy?

Table 2
Mean Achievement Scores and Standard Deviations of Male and Female Students in Physics Taught Using CMS

Group	Gender	*N*	Pre-test mean	*SD*	Post-test mean	*SD*	Mean gain
CMS	Male	41	17.15	2.97	32.63	4.37	15.48
	Female	18	15.78	2.37	33.11	4.28	17.33
	Difference		1.37		.48		1.85

Results in Table 2 reveal a post-test mean score of 32.63 with a standard deviation of 4.37 for male students taught Physics using CMS. On the other hand, female students who taught Physics using CMS had a post-test mean score of 33.11 with a standard deviation of 4.28. The difference between the pre-test and post-test mean scores of the male students is 15.48 and that of the female students is 17.33. These differences show what was achieved by the male and female students. The difference between the post-test mean scores of the two sexes is 0.48 and the mean gained in favour of the female students is 1.85. The implication is that the female students who taught Physics using CMS gained more achievement than their male counterparts. However, this suggests that student's mean post-test scores across gender and methods of instruction are negligible.

Research question 3: What is the difference in mean academic achievement scores of male and female students in Physics taught using GDM? Results in Table 3 show the post-test mean score of 23.75 with a standard deviation of 4.92 for male students taught Physics using the GDM, while female students taught Physics using the GDM had a post-test mean score of 22.88 with a *SD* of 3.90. The difference between the pre-test and post-test mean scores of the male students

is 7.44 and that of the female students is 6.84. These differences show what was achieved by the male and female students. The difference between the post-test mean scores of the two sexes is .87 and the mean gained in favour of the male students is .60. The implication is that the male students who taught Physics using the GDM gained more achievement than their female counterparts. However, this suggests that student's mean post-test scores across gender and methods of instruction is negligible.

Table 3
Mean Achievement Scores and Standard Deviations of Male and Female Students in Physics Taught Using GDM

Group	Gender	*N*	Pre-test mean	*SD*	Post-test mean	*SD*	Mean gain
GDM	Male	32	16.31	2.43	23.75	4.92	7.44
	Female	24	16.04	2.46	22.88	3.90	6.84
	Difference		.27		.87		.60

Hypothesis 1: There is no statistically significant difference in the mean academic achievement scores of students taught physics using CMS and those taught using the GDM.

Table 4 is a one-way ANCOVA to compare the effect of CMS and GDM on student's achievement in Physics. The result F (1, 112) = 153.510, p = .000 < .05 shows that the two groups differ significantly. Thus, the null hypothesis is rejected. Therefore, there is a significant difference in the mean academic achievement scores of students taught physics using the CMS and those taught using the GDM. The effect size (eta square = .578) is high and it indicates that 57.8% of the difference in the mean score is based on the strategy used. The results revealed that the method of teaching produced a significant difference in the post-test achievement scores of students when the covariate effect (pre-test) was controlled.

Table 4
One-way Analysis of Covariance of the Mean Achievement Scores of Students in CMS and GDM Groups

Sources of variation	Sum of squares	*df*	Mean square	*F*	*p*	Partial eta squared
Corrected model	3026.101[a]	2	1513.051	100.220	.000	.642
Intercept	607.940	1	607.940	40.268	.000	.264
Pretest	494.603	1	494.603	32.761	.000	.226
Group	2317.579	1	2317.579	153.510	.000	.578
Error	1690.890	112	15.097			
Total	96226.000	115				
Corrected total	4716.991	114				

Note. [a] R Squared = 0.642

Hypothesis 2: There is no statistically significant difference in the mean academic achievement scores of male and female students taught physics using the CMS.

Table 5 is a one-way ANCOVA to compare the effect of CMS on male and female student's achievement in Physics. The result F (1, 56) = 1.422, p = .238 > .05 shows that the variation of scores for male and female students of the CMS group is the same. Thus, the null hypothesis is not rejected. Therefore, there is no statistically significant difference between the mean achievement scores of male and female students taught Physics using CMS. The effect size (eta square = .025) is very low and it indicates that only .25% of the difference in the mean score is based on gender.

Table 5
One-way Analysis of Covariance of the Mean Achievement Scores of Male and Female Students Taught Physics Using CMS

Sources of variation	Sum of squares	*df*	Mean square	*F*	*p*	Partial eta squared
Corrected model	195.210[a]	2	97.605	6.191	.004	.181
Intercept	781.149	1	781.149	49.545	.000	.469
CMS-pre-test	192.365	1	192.365	12.201	.001	.179
CMS-gender	22.426	1	22.426	1.422	.238	.025
Error	882.925	56	15.767			
Total	64474.000	59				
Corrected total	1078.136	58				

Note. [a] R Squared = .181 (Adjusted R Squared = .152)

Table 6
One-way Analysis of Covariance of the Mean Achievement Scores of Male and Female Students Taught Physics Using GDM

Source	Sum of squares	*df*	Mean square	*F*	*p*	Partial eta squared
Corrected model	376.211[a]	2	188.106	13.636	.000	.340
Intercept	30.446	1	30.446	2.207	.143	.040
GDM-pre-test	366.687	1	366.687	26.581	.000	.334
GDM-gender	7.058	1	7.058	.512	.478	.010
Error	731.146	53	13.795			
Total	31752.000	56				
Corrected total	1107.357	55				

Note. [a] R Squared = .340 (Adjusted R Squared = .315)

Hypothesis 3: There is no statistically significant difference in the mean academic achievement scores of male and female students taught physics using the GDM.

Table 6 is a one-way ANCOVA to compare the effect of the GDM on male and female student's achievement in Physics. The result F (1, 53) = .512, p = .478 > .05 shows that the variation of scores for male and female students of the GDM group is the same. Thus, the null hypothesis is not rejected. Therefore, there is no statistically significant difference between the mean achievement scores of male and female students taught Physics using GDM. The effect size (eta square = .010) is very low and it indicates that only .10% of the difference in the mean score is based on gender.

Discussion

The result of this study has shown that students taught physics using CMS performed better than their counterparts taught using the GDM. The post-test mean scores of the CMS students were found to be significantly different from those of their colleagues in the GDM group; this, therefore, implies that the two treatments are not of equal strength. The finding has revealed the effectiveness of the use of the CMS in enhancing student's achievement in Physics. The finding of this study agrees with that of Usman and Mankilik (2019) conducted in the northeast region of Nigeria, Doris (2018) study in the central part of Nigeria, as well as Awodun's (2017) study in the southwest region of Nigeria, whom all affirmed that students instructed with concept mapping performed significantly better than those instructed with the conventional teaching method. However, this finding contradicts Jack and Suleiman's (2020); Auta (2015) studies which revealed that students taught using Guided-Inquiry instructional strategy, had significantly higher academic achievement than their counterparts taught using CMS.

The use of the CMS was more effective in teaching Physics than the GDM. This was due to the fact that the process of drawing a concept map by students makes the task of revision more effective and simple and significantly makes learning more meaningful, which consequently facilitates student's achievement. More so, concept mapping attracts student's attention, motivates them, facilitates recall of information and hence, enhances their achievement. Jaya (2015) asserted that to be successful in learning; students have to take the passion of knowledge actively by seeking expert conceptual linkages between new concepts and those they already possess. Concept learning breaks down the task to be learned into smaller units. These smaller units serve as the key to each segment of the problem, as the learning maps each unit to the key ideas. The strategy thus visualizes the structure of knowledge as a means of representing frameworks for the interrelationship between concepts as an instructional and assessment tool to facilitate meaningful learning. Concept mapping combines visual learning with the spatial representation of information to promote meaningful conceptual learning. These attributes of concept mapping must have accounted for the better performance by students exposed to concept mapping compared to the GDM.

The results indicate that the gender differences are not statistically significant since the calculated probability of .238 and .512 for CMS and GDM group respectively is greater than .05 level of significance. This means the variation of scores for male and female students is about the same. The finding of this study agrees with Okoronka (2018), Uwem and Macmillan (2012) findings which showed that the academic achievement of both male and female students was not significantly different. This implies that both teaching methods are gender-friendly as both male and female participants benefitted from them. This is because their academic performances were not significantly different on the basis of their sex status. When a strategy is interactive, makes the learner active and provides some steps that engage them virtually and mentally, the gender of the learner will not be relevant. This is precisely the case with CSM and GDM.

Conclusion

It is evident from the findings of this study to conclude that the use of the CMS provided the opportunity for students to learn better and achieve better in Physics compared to the GDM. The mean academic achievement scores of male and female students who taught physics using the CMS and GDM were not too different, implying that both strategies are not gendering sensitive. Both sexes are capable of competing and participating in classroom activities when the two strategies are being used.

Recommendations

Based on the findings, the following recommendations are made.

1. Physics teachers should be encouraged to use CMS while teaching Physics concepts to actively involve the students in identifying relationships in concepts and also use that as a tool to arouse the leaner's interest.
2. Physics teacher trainees should be trained on the use of the CMS and students should be encouraged to draw a concept map of the topic being taught after teaching.
3. The female, as well as male students, benefitted equally when taught physics using concept mapping. Based on this finding, the female and male students should be encouraged to enthusiastically pursue most of the physics courses since most of the abstract concepts can now be explained using concept maps.

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