EFFECT OF DIGITAL MIND MAPPING ON STUDENTS' ACHIEVEMENT IN MATHEMATICS

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ABSTRACT
The digital mind-mapping instructional approach employs the capacity of technological interventions in learning spaces to enhance students' cognition and consequent achievement. The present study sought to determine the effect of digital mind mapping on students' achievement in mathematics. Three research questions and three hypotheses guided the study. The quasi-experimental study sampled 369 SS II students in the Agbani education zone of Enugu state using multistage sampling. The result of this study revealed a significant difference in favour of the Mathematics achievement of students taught with digital mind mapping method. However, it was found that the male students taught with the digital mind mapping method slightly achieved an insignificant higher level of mathematics than the females in the same group. Still, there was no significant interaction between gender groups and the teaching methods. The study concluded on the necessity for adopting digital mind mapping instructional method into learning spaces to enhance students' achievement in Mathematics. The study recommended support, training, and encouragement for teachers and school administrators to adopt digital mind-mapping instructional techniques for Mathematics instruction, among others.

Keywords: Digital Mind Mapping, Mathematics, Mind Mapping, Xmind, Achievement

Introduction
Digital technology has continued to lend effectiveness in reimagining learning spaces, especially in the sciences. Science and technology have been two pseudo-distinct but intertwined learning domains. While science encapsulates the systematic study of the

form and characteristics of the physical and natural world through observation, investigation, and testing of the fit of models via available evidence, technology embodies the application of this scientific knowledge. Egbagah (2012) holds that scientific and technological advancement is pivotal to the developmental trajectory of a country, especially a developing one such as Nigeria. However, Mathematics resides at the fulcrum of scientific and technological exploits, and in almost all areas of life.

The position of the national policy on education recommends Mathematics as a "core subject" up to the end of secondary school education; it is no wonder the huge interest of researchers and stakeholders in students' Mathematics achievement. The unsatisfactory achievement of students in Mathematics has remained a worrisome re-occurrence at external examinations, especially at the National Examination Council (NECO) and West African Examination Council (WAEC). Pieces of evidence from successive chief examiner's reports show how worrisome this problem has become to the scientific and technological advancement of Nigeria. Besides the efforts of the government and researchers to abate this worrisome state of affairs in students' achievement in Mathematics, the problem persists as students continue to underperform, while some resort to examination malpractices (Onyema, et al., 2019).

A plethora of researchers have investigated the likely reason for poor students' Mathematics academic achievement at external examinations from different viewpoints. Some studies suggest that this could be a result of students' apathy (Iji, 2010), deficiency of required soft skills such as emotional intelligence (Nnaji, et al., 2020), congested classrooms and teachers' ineffectiveness (Eze, 2011), dilapidated and insufficient infrastructure (Anyor & Amo, 2017), insufficient funding (Kurumeh, 2007), school management problems and social-political instabilities (Yara & Otieno, 2010). However, the present study draws attention to the instructional efficacy adopted for teaching this very important subject.

Literature assert that students often find it tough to conceptualise new mathematical concepts and build a linkage with previous knowledge which is necessary for the understanding of new concepts. This not only puts the students in difficult situations, but also discourages them, leading to frustration which could worsen the learning situation, according to the theory of learning by Ausubel (1968). Hence the need to map concepts to show the interconnections and linkages between already known or familiar concepts with the new knowledge presented to the students. Digital devices present an enhanced learning experience with better pictures and images which could be better interpreted by the "digital native" students in our classrooms today (Parker, 2021). Hence, it is supposed that the digital age student learns better in such an enhanced environment, hence the introduction of digital advantage devices for mind mapping may encourage the student and buffer the challenges associated with the Lecture teaching method.

Mind maps are logical organisation of the interrelationships between ideas and concepts in graphical representation forms. The idea begins with a centralised topic, and then branches out with labels and links, notes, pictures, symbols, among others (Safdar,

et al., 2012). Mind mapping is a graphical association of key concepts to elicit salient ideas between concepts in focus. Mind mapping is proven to be very efficient in organising cognitive frameworks into powerful integrated patterns. Mind mapping has been associated with an enhancement in mental focus, assimilation, and efficiency in information processing. Some mind mapping Software available include ClickUp, XMind**,** ConceptDraw MINDMAP, MindManager, Edraw Mind Map, Miro, MindMeister, Coggle, Lucidchart, Mindly, Gitmind, Canva, InfoRapid KnowledgeBase Builder and Scapple among others, some of which run on the iOS, Android or Windows operating system. XMind mind mapping application which can run on both Windows and Android operating systems can provide a simple algorithm for problem-solving, a technique which has been effective in the cooperate and computer programming world could be adapted to suit the learning needs of Mathematics students in order to abate the poor academic achievement in Mathematics observed over the years (Ahmad & Munawar, 2013; Ganiyu & Munawar, 2013; Luchembe, et al., 2014).

Researchers have agreed largely on the need to investigate the perceived disparity in students' academic performance due to gender differences. The socio-cultural stratification of individuals as either male or female which connotes the subject of gender has widely been suggested to impact the achievement of students, in favour of females, (Voyer & Voyer, 2014), while studies by Eze, et al. (2015) and Adeyemi (2017) favour male students; the acceptance, perception and use of technological tools in learning tilt to the favour of the males (Yau & Cheng, 2012), while Danko, et al., (2020)'s study favours females. More so, no significant difference in the achievement of male and female students was found by Dania (2014) and Jekayinfa, et al., (2023). It is however still uncertain if males or females will achieve more in Mathematics instruction when exposed to digital mind mapping or lecture instructional methods. Therefore, the present study deems it necessary to investigate the effect of digital mind mapping on students' academic achievements in Mathematics.

Research Questions

These research questions guided this study:

1. What is the mean difference in the Mathematics achievement scores of students taught via digital mind mapping and lecture method of teaching?
2. What is the mean difference in the Mathematics achievement scores of male and female students taught via digital mind mapping and lecture methods?
3. What is the effect of interaction due to digital mind mapping and lecture methods of instruction and students' gender on their Mathematics achievement?

Hypotheses

These research hypotheses guided this study:

1. The Mathematics achievement scores of students due to digital mind mapping does not significantly differ from those taught via lecture instructional method.

2. The Mathematics achievement scores of students taught via digital mind mapping and lecture methods does not significantly differ based on gender.
3. Instructional methods does not significantly interact with gender.

Methods

Quasi experimental design, involving pretest-posttest nonequivalent control-group research design was employed in the study. Quasi experimental design, involving pretest-posttest nonequivalent control-group research design is more suitable in studies which sample intact classes to estimate the causal effect of digital mind mapping on students' achievement in Mathematics (Nworgu, 2015). The study sampled 369 senior secondary school two (SS II) students from a population of four thousand, seven hundred and seven (4,707) SS II students in the forty-four (44) public secondary schools in the three local government areas (LGAs) which constitute Enugu education zone of Enugu state, using Taro Yamane's formula. A multistage sampling procedure was adopted for the study. First, the researchers randomly sampled two out of the three LGAs (i.e Nkanu-East and Nkanu-South LGAs) in the educational zone from which a purposive sample was adopted to exclude single-sex schools, leaving eighteen coeducational schools which have a functional Computer or Information and Communication Technology (ICT) facility for the study. Then, disproportionate stratified sampling technique was employed to draw students from schools in each of the two LGAs from which intact classes of students were sampled.

The instrument by which data was collected was a dichotomously scored forty-item achievement test titled "Mathematics Achievement Test" (MAT) designed by the researchers using the content scope of SS II Mathematics for a detailed table of specification, and face validation following the study's purpose by three experts. Their suggestions and recommendations were adhered to. "Section A" contained demographic information such as gender while "Section B" contained the MAT forty items. Upon trial testing on students of a school in Enugu-East LGA, but shared the same characteristics with the study population, MAT returned with a Kuder-Richardson 20 reliability index of 0.86.

Experimental Procedure

The study involved two stages, which were the administration of the pre-test and post-test for the MAT. The regular Mathematics teachers were used in the selected schools as research assistants in order to avoid Hawthorne effect. The teachers were trained by the researchers to ensure uniformity in instructional approach, following the researchers' prepared lesson plans for the control and experimental groups, and the modalities of the experiment. Lecture teaching method and digital mind mapping method using Xmind application on the Windows computer for teachers and Android for students were employed in the control and experimental groups, using associate lesson plans by their normal class teachers respectively. After, a twenty-eight days experimental period, a posttest MAT was administered to the control and experimental groups and retrieved on

the spot after the allotted time of one hour. The retrieved responses were scored, for which the maximum possible score was forty while the minimum was zero, and used for analysis of the data.

The Extraneous variables which could introduce bias or errors in the course of the experiment were controlled through the following procedure:

- Subject interaction: In order to avoid interaction between experimental and control groups, the experimental and control groups were not selected from the same school.
- Teacher variables: Prior to the commencement of treatment, the researchers trained the regular teachers, and explained the pattern and procedure for the study.
- Hawthorne's effect: The researchers used regular classroom teachers in each of the sampled schools as research assistants for the study in order to avoid any suspicion leading to a change in student's behaviour which could affect their results.
- Instructional situation variables: The researcher prepared and provided teachers in respective schools with the appropriate lesson plans for each group, used for the lesson in order to ensure proper monitoring of the experiment.

To analyse the data collected from the study, mean and standard deviation were used to answer the research questions; while analysis of covariance (ANCOVA) was used to test the hypotheses at 0.05 level of significance. The null hypothesis was rejected with p-values less than the level of significance.

Results

Table 1: Mean Achievement Scores of Students Taught Mathematics using Digital Mind Mapping and Lecture Method

		Pre-Test		Post-Test			
Groups	**N**	$\bar{x}$	**SD**	$\bar{x}$	**SD**	**Gain**	**Difference**
Digital Mind Mapping	185	22.08	3.82	29.82	3.77	7.74	7.09
Lecture Method	184	22.09	3.59	22.74	5.02	0.65	

Key: $\bar{x}$ = Mean, SD = Standard Deviation

Table 1 shows that the Mathematics mean achievement scores of students taught with digital mind mapping and those taught using lecture method. The pre-test mean score of the students taught Mathematics using digital mind mapping method was 22.08 with a standard deviation of 3.82, while their post-test mean achievement score was 29.82 with standard deviation of 3.77; and those taught with lecture method had a pre-test mean score of 22.09 with a standard deviation of 3.59 while their post-test mean achievement score was 22.74 with standard deviation of 5.02. The result indicated a mean Mathematics achievement score difference of 7.09 in favour of the students taught Mathematics using digital mind mapping method, after mean gains of 7.74 and 0.65 respectively. The result reveals that the students taught with digital mind mapping method achieved higher in Mathematics than those taught with lecture method.

Table 2: Summary of Analysis of Covariance (ANCOVA) of Students' Post-test Achievement Scores in Mathematics by Method and Gender

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5982.430[a]	4	1495.608	92.676	.000	.505
Intercept	2209.671	1	2209.671	136.923	.000	.273
Pretest	1330.847	1	1330.847	82.467	.000	.185
treatment Groups	4670.626	1	4670.626	289.417	.000	.443
Gender	24.898	1	24.898	1.543	.215	.004
Groups * Gender	21.539	1	21.539	1.335	.249	.004
Error	5874.245	364	16.138			
Total	266853.640	369				
Corrected Total	11856.675	368				

a. R Squared = .505 (Adjusted R Squared = .499)

The result shown on Table 2 show the significance of Mathematics achievement scores of students taught using digital mind mapping and those taught using lecture method. The result indicate that the F value of 289.417 with a p-value of 0.000 in respect of instructional groups is significant at 0.05 level of significance with an associated effect size of 0.443; indicating a 44.3% increase in the achievement scores of students due to the favoured instructional method. Hence the null hypothesis one which states that Mathematics achievement scores of students taught using digital mind mapping does not significantly differ from those taught using lecture method is rejected. This means that at 0.05 level, the Mathematics achievement scores of students taught using digital mind mapping is significantly different from those taught using lecture method. The result shows that the use of digital mind mapping method significantly improved students' achievement in Mathematics than case in the lecture method.

Table 3: Mean Achievement Scores of Male and Female Students Taught Mathematics using Digital Mind Mapping

		Pre-Test		Post-Test			
Groups	N	$\bar{x}$	SD	$\bar{x}$	SD	Mean Gain	Mean Difference
Male	204	21.93	3.84	26.36	5.91	4.43	0.51
Female	165	22.28	3.52	26.20	5.39	3.92	

Table 3 shows the Mathematics mean achievement scores of male and female students taught with digital mind mapping method. The pre-test mean score of the male students was 21.93 with a standard deviation of 3.84, while their post-test mean achievement score was 26.36 with standard deviation of 5.91; and the females had a pre-test mean score of 22.28 with a standard deviation of 3.52 while their post-test mean achievement score was 26.20 with standard deviation of 5.39. The result indicated a mean Mathematics achievement score difference of 0.51 in favour of the males, after mean gains of 4.43 and

3.92 respectively. The result revealed that the male students slightly achieved higher in Mathematics than the females.

The result in Table 2 shows the significance of Mathematics achievement scores of male and female students taught with digital mind mapping and lecture methods. The result indicates that the F value of 1.543 with a p-value of 0.215 with respect to the gender groups is not significant at 0.05 level of significance with associated effect size of 0.004; indicating only a 0.4% increase in the achievement scores of students due to gender difference. Hence the null hypothesis two which states that Mathematics achievement scores of students taught using digital mind mapping and lecture methods does not significantly differ based on gender is not rejected. This means that at 0.05 level, the mathematics achievement scores of students taught using digital mind mapping and lecture methods is not significantly different.

Table 4: Interaction Effect of Digital Mind Mapping Method and Gender on Students' Achievement Scores in Mathematics

		Pre-Test		Post-Test				
Groups		**N**	$\bar{x}$	**SD**	$\bar{x}$	**SD**	**Mean Gain**	**Mean Difference**
Digital Mind Mapping	Male	100	22.03	3.91	29.82	3.77	7.79	
	Female	85	22.12	3.73	29.83	3.78	7.71	0.08
Lecture	Male	80	21.82	3.79	23.03	5.68	1.12	1.02
	Female	104	22.45	3.30	22.35	4.00	0.10	

Table 4 shows that the male students taught Mathematics by digital mind mapping method had a pre-test mean achievement score of 22.03 with Standard Deviation of 3.91, and a post-test mean score of 29.82 with Standard Deviation of 3.77. However, the female students taught Mathematics by digital mind mapping method had a pre-test mean achievement score of 22.12 with Standard Deviation of 3.73, and a post-test mean score of 29.83 with Standard Deviation of 3.78. With a difference of 0.08 after mean gains of 7.79 and 7.71 for the male and female students respectively, the male interacted better with the digital mind mapping method. Again, table 5 shows that the male students taught Mathematics by lecture method had a pre-test mean achievement score of 21.82 with Standard Deviation of 3.79, and a post-test mean score of 23.03 with Standard Deviation of 5.68. However, the female students taught Mathematics by lecture method had a pre-test mean achievement score of 22.45 with Standard Deviation of 3.30, and a post-test mean score of 22.35 with Standard Deviation of 4.00. With a difference of 1.02 after mean gains of 1.12 and 0.10 for the male and female students respectively, the males interacted better with the lecture method.

The interaction effect of instructional methods and gender as shown in Table 2 and Figure 1 is not significant. This is because the F value of 1.335 with respect to the

interaction between instructional method and gender is shown to be not significant with a p-value of 0.249 at 0.05 level of significance. The associated interaction effect size of 0.004 as shown in Table 2 indicates that only 0.4% of variance in the mean achievement score of students in Mathematics was due to the interaction of instructional method and gender. Figure 1 also depicts further that there is no significant intersection (interaction) between the gender groups on the instructional methods. Therefore, the null hypothesis three which states that instructional methods do not significantly interact with gender is upheld; there was no interaction between students taught Mathematics by digital mind mapping and lecture methods and their gender.

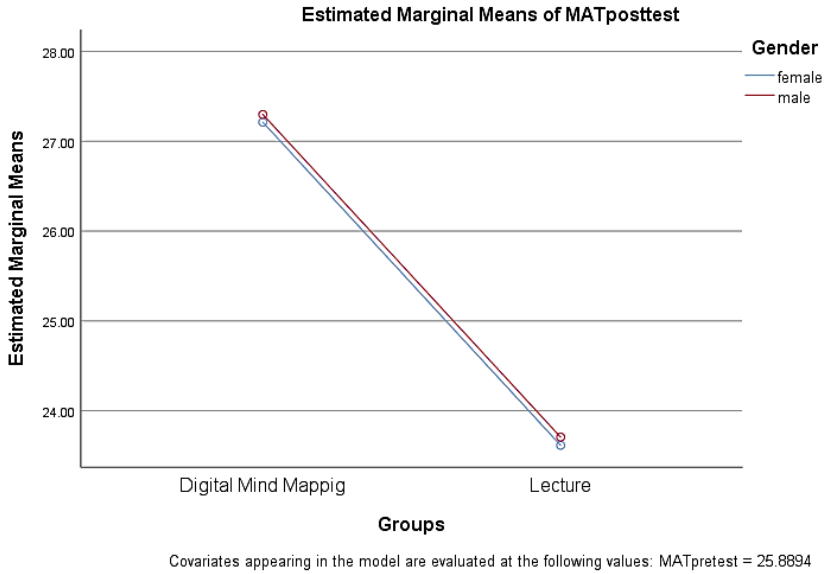

Figure 1: Graph of Interaction Effect of Instructional Groups and Gender on Students' Achievement

Discussion

The result of this study reveals that the students taught with the digital mind mapping method achieved significantly higher in Mathematics than those taught with the lecture method. This implies that the introduction of digital mind mapping method can significantly improve students' achievement in Mathematics than the orthodox lecture method currently in use. The result is plausible chiefly because the students interact with digital resources that help them build a connection between previous and current knowledge, thereby improving comprehension and perhaps retention. These findings validate the postulates of Ahmad and Munawar (2013), Ganiyu (2013), and Luchemb, et al., (2014) confirming that digital mind mapping method of instruction improves students' achievement in Mathematics and could do the same in other school subjects and life in general.

The findings of this study have revealed that the male students slightly achieved higher in Mathematics than the females. Although this was not significant, it may not be

ignored. The findings may have been so due to the phobia students often experience in the subject and the high emotional dispositions associated with the female gender, according to Nnaji, Eze and Madu (2020). Also, it is possible because female students often shy away from such subjects with calculations and high mental demands for problem-solving as is the case with Mathematics. The finding has further strengthened the positions of Eze, et al., (2015) and Adeyemi (2017) that male students achieved higher in Mathematics.

The result of the study also showed that male students interacted better with both instructional methods. With less mean difference recorded in digital mind mapping method, although not significant, and in favour of the male students in both methods, the evidence shows the closing gaps between the genders in the learning of Mathematics. This is a position which previously assigned technological roles to males and less technical roles to females. This gap might also be closing due to the introduction of digital mind mapping technology, which may be of advantage to female students in learning Mathematics. Again, the result may be so because some advocacy efforts targeted at awakening the Mathematics zeal of female students may already be yielding the desired results.

Recommendations and Conclusion

In conclusion, the findings of the study show that the introduction of digital mind mapping technique in Mathematics instruction has shown to significantly improve students' achievement in Mathematics, although, it has not significantly favoured any gender group over the other. However, the availability of smart devices capable of running the software was challenging since many schools had poorly equipped or nonfunctional computer laboratories or ICT units. This is especially the case in rural schools, in addition to poor power supplies for the effective running of the Windows and Android software. Most teachers encountered in the field have low knowledge of operating smart devices which posed a challenge to the study also. Hence the following recommendations were made by the researchers:

1. The researchers recommend, in light of the findings of this study, that educational policymakers and curriculum planners should adopt the use of digital mind mapping, and make policies that will facilitate its funding since it requires huge capital investment for smooth implementation of the instructional method.
2. Government should partner with technology companies to introduce the effective use of digital mind mapping strategy in the training program of pre-service and in-service teachers.
3. Based of the findings of the study, serving teachers and school administrators should be trained and empowered with the knowledge, skill and resources for smooth implementation and use of digital mind mapping in instructional spaces for the benefit of improving students' achievement in Mathematics, when the policy is adopted.

4. Parents should also endeavour to support and encourage their children, teachers and schools to adopt digital mind mapping in Mathematics instruction.
5. Further studies should investigate the use of other types of mind-mapping applications, and expand to other subjects. Further studies should also look at the effect of the digital mind-mapping instructional technique on students' psycho-social variables associated with learning. Further studies may also investigate the predictive power of digital mind mapping on students' achievement.

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