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Effect of concept mapping instructional strategy on senior secondary school students' retention level in biology in Kwara State

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ABSTRACT

Cell Division topic in Biology is often challenging for students due to poor understanding. The study investigated how concept mapping impacts the retention of senior secondary school biology students in Kwara State, Nigeria. Using a quasi-experimental design with 77 students from two public junior high schools. The design is suitable due to its limitations, such as the inability to assign participants and the use of pre-existing groups randomly. Data was collected using Biology Concept Map Instructional Strategy for Teaching Cell Division and Biology Performing Test. The instruments were validated by experts and tested on 40 students. The results showed a significant difference in retention levels between male and female students when teaching Cell Division using this strategy ($p<0.05$). It is recommended that Biology teachers prioritize the use of Computer-Machine Interfaces when teaching Cell Division, particularly for students with low retention and female students. The concept mapping instructional strategy significantly improves students' retention levels in Cell Division Biology, particularly among female students. It also indicates that gender is greatly influenced by this strategy, with females showing higher retention rates. Therefore, it suggests that using this approach in senior secondary school biology education can significantly enhance retention rates.

INTRODUCTION

The National Policy on Education in Nigeria, as outlined by the Federal Republic of Nigeria (2013), aims to enhance the biology curriculum in Nigerian secondary schools by equipping students with practical laboratory and field skills, imparting relevant knowledge in biology, and fostering a scientific mindset. Consequently, the curriculum evaluates the status of biology education in Nigerian senior secondary schools and its significance in cultivating a scientifically literate society. Despite the pivotal role of biology in societal progress, various factors impede the effective teaching and learning of the subject in secondary schools. Issues such as inadequate teaching methods utilized by educators (Ahmed & Abimbola, 2011; Ali et al., 2014; Uchegbu et al., 2016) and the abstract nature of biological concepts like Cell Division (Chattopadhyay, 2012; Cimer, 2012) act as barriers to biology education, prompting science educators and researchers to explore alternative approaches to enhance biology instruction in senior secondary schools.

A concept map serves as a graphical representation of interconnected knowledge, illustrating the relationships between various topics. Essentially, it comprises concepts linked by lines or arrows denoting the connections between them. These concepts are typically enclosed in circles or boxes (Awofala 2011). Concept maps are utilized to visually convey ideas, concepts, and information, aiding students in comprehending the relationships between different ideas, identifying connections between concepts, exploring related topics, and structuring information logically and visually. The academic proficiency of students in biology is influenced by multiple factors. Bizimana et al. (2022) revealed that resources such as funding, laboratory equipment, personnel, and instructional materials hinder the teaching and learning of biology, as well as students' retention of the subject. According to Malik et al. (2020), teaching methods also impact students' retention in biology, emphasizing that students' perception of knowledge and achievement guide teachers in adapting teaching strategies to enhance learning outcomes.

Various individual and contextual factors, including personal, familial, social, and academic variables, such as school environment, are crucial in influencing students' engagement with education and retention levels (Gandra & Cruz, 2021). Learning retention is paramount in teaching and learning, as students often excel in classroom learning but struggle in tests and examinations (Toheed et al., 2017). Retaining acquired knowledge involves storing information in long-term memory for easy recall (Bennett & Rebello, 2019; Forsberg et al., 2021). It entails encoding new knowledge into long-term memory to facilitate effortless recollection when needed in the future. However, failure to retain knowledge results in the information being stored in short-term memory.

There has been a decline in the average level of student retention in science education subjects, particularly Biology (Nkpordee & Ibinabo, 2022). The researcher has noted a consistent decrease in students' retention levels in external biology examinations. Additionally, reports from the WAEC Chief Examiner have identified weak areas among students, such as inadequate labelling, poor organization, and difficulties in connecting concepts in Biology (Chinyere & Isaiah, 2019). The primary areas of weakness observed among Biology students in the WASSCE exams conducted in Nigeria include incomplete and unlabeled diagrams, imprecise labelling, disjointed content, and unclear illustrations. The study investigated the impact of utilizing concept mapping instructional strategies on enhancing the retention levels of senior secondary school students in biology in Kwara State.

Purpose of the study

1. To determine the difference in the pretest and posttest performance of Biology Students taught using Concept Mapping Instructional Strategy (CMIS).
2. To examine the difference in the retention levels of male and female Biology students taught using (CMIS).

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Research questions

1. What is the difference in the pretest and posttest retention level of Biology Students when Concept Mapping Instructional Strategy is used to teach Cell Division?
2. What are the retention levels of male and female students taught using (CMIS)?

Research hypotheses

Ho_1: There is no significant effect of Concept Mapping Instructional Strategy (CMIS) on the retention of Biology students.

Ho_2: There is no significant effect of gender on the retention level of Biology Students when Concept Mapping Instructional Strategy is used to teach Cell Division

Theoretical framework

This research is based on Constructivism Theory, developed by Vygotsky in 1978. Constructivism suggests that learners construct personal meaning through experiences, influenced by prior knowledge and novel events. It emphasizes active engagement in the educational journey, where knowledge is built on experiential foundations. As events unfold, individuals reflect on their experiences and integrate new concepts, developing cognitive frameworks to organize acquired information. At the core of constructivism lies the notion that students acquire the skill of learning itself. Understanding the theory of constructivist learning is crucial for comprehending the process of student education. The fundamental tenet of constructivism is that students play an active role in constructing knowledge and integrating new experiences with preexisting understandings. As Woolfolk (1993) aptly stated, learning is an active cognitive process, not a passive reception of information. Educators can employ various forms of constructivism, such as cognitive and social constructivism, to effectively implement this learning theory.

Cognitive constructivism emphasizes aligning learning with the learner's cognitive developmental stage. This approach facilitates the acquisition of new knowledge by linking it to existing cognitive structures, enabling learners to adapt their mental frameworks to accommodate novel information. Rooted in Jean Piaget's research on children's cognitive development, cognitive constructivism underscores the collaborative nature of learning. Knowledge formation is shaped by interactions with others, one's cultural milieu, and broader societal influences. Learners rely on social interactions to construct their knowledge base, with peer and societal factors playing a significant role in this process. According to Piaget, a schema represents the fundamental unit of knowledge, gradually accumulating over an individual's lifetime. Cognitive learning is an active educational modality that aims to optimize learners' cognitive capacities. By facilitating the integration of new information with existing cognitive structures, cognitive learning enhances memory and retention capabilities. Retention, defined as the brain's ability to absorb and store information through sensory experiences and cognitive processes, is a key component of cognition.

Literature review

Eze and Madu's (2022) study found that concept mapping improved secondary students' Geometry performance, with 310 students from four Kano schools participating, and increased academic achievement and interest in the subject. Results showed concept mapping improved academic achievement and interest in Geometry. Bizimana et al. (2022) analyzed biology retention among 3,129 students in Rwanda. Differences were found based on gender, school type, and location. Bizimana et al. (2022) studied the retention of biology students in public lower secondary schools in Nyamagabe district, Rwanda, based on gender, type, and school location. They analyzed 3,129 students' biology grade scores from the 2018 Ordinary Level Biology National Examination.

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The results showed significant differences in retention levels based on gender, school type, and location.

Bichi et al. (2019) studied the academic achievement of Senior Secondary School students in Biology, focusing on gender differences. They used an ex post facto approach and collected data from 200 students in Kano State, Nigeria. The study revealed a significant gender disparity in biology retention levels among urban and rural school students in Kano State. A study by Adebisi et al. (2021) investigated the impact of concept mapping instructional strategies on the achievement of Senior Secondary School students in Biology in Lagos State, Nigeria. The study used a quasi-experimental design and included two intact classes of SS 2 students. Data was collected using the Biology Achievement Test (BAT) and Concept Mapping Based Lesson Plan (CMLP). The results showed that the experimental group outperformed the control group, indicating that concept mapping positively impacted students' retention. The study highlights the gender disparity in biology retention levels in Kano State. Adeniran et al.'s (2018) study found that concept mapping improved Basic Science retention in Nigerian junior secondary students. The study involved 1,384 participants, with 310 students from four Government Secondary Schools. The results showed that students taught with concept mapping had higher retention scores (52.72) compared to conventional methods (33.22).

METHODS

The study aims to investigate the effect of concept mapping on senior secondary school students' retention in biology in Kwara State using a quasi-experimental research design. The design is suitable due to its limitations, such as the inability to randomly assign participants and the use of pre-existing groups. The study focuses on comparing retention levels between students taught using concept mapping and those taught using traditional methods. Researchers can control for extraneous variables by matching groups based on pre-existing characteristics, using standardized tests and teaching materials, and controlling for teacher effects. However, the lack of random assignment and potential for confounding variables make it difficult to isolate the intervention's effect. Careful data analysis and consideration of potential confounding variables are essential for drawing meaningful conclusions. The study focused on a target population of 852 Secondary School Students in SSS II from two selected public senior secondary schools in Ilorin, Kwara State. The sample size consisted of 77 Senior Secondary School II Biology students who were purposively selected from two Public Secondary Schools in Ilorin, Kwara State, Nigeria. The selection process was based on the tally card. The decision to focus on SS II students was grounded in the fact that the topic of Cell Division is typically covered at this class level. Students were categorized into high, average, and low scoring and retention levels based on their performance on the Biology Performance Test (BPT).

Two instruments were employed for data collection in this study. The first instrument utilized was adapted from Liu and Lee (2013), and Kaymaz & Doğru (2024) Biology Concept Map Instructional Strategy for Teaching Cell Division (BCMISTCD). The validity of these instruments was confirmed by providing the draft copy to three experts in the Department of Science Education, an expert in Cell Biology from the Faculty of Science, and an expert in Test and Measurement from the Faculty of Education, all affiliated with Al-Hikmah University, Ilorin. The reliability of the instruments was assessed through pilot testing on 40 Senior Secondary School Students from a separate school not involved in the main study. Data analysis involved the use of frequency count, percentage, mean, and standard deviation to address research questions 1-2. Additionally, Analysis of Covariance (ANCOVA) was employed to test null hypotheses 1-2 at a significance level of 0.05. Students were classified as having low retention levels if they scored between 0-39% on the Biology Retention Level Test (BPT), average retention levels if they scored between 40-59%, and high retention levels if they scored between 60-100%. IBM Statistical Package for Social Science (SPSS) version 25 was utilized for data analysis and storage. Students' retention level was

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determined based on their post-test and post-posttest performance in the Biology Performance Test (BPT). The retention level was categorized into low, average and high. Therefore, low retention was (0-39%), Average retention level score was (40-59%) and high retention level was (60-100%). The low retention level (0-39%), Average retention level (40-59%), and High retention level (60-100%) was to set the benchmark score for measuring students' retention levels. This was determined from the student's score on the Biology Performance Test (BPT).

RESULTS AND DISCUSSION

Research questions 1

The result of pretest and post-test retention level after using concept mapping strategy can be seen in Table 1.

Table 1. Difference in the pretest and post-test retention level of biology students with the use of concept mapping instructional strategy to teach cell division

Academic Retention Level	Pretest	Post-test	Post-posttest
Lowest Retention level	45.00	46.00	64.00
Highest Retention level	65.00	78.00	99.00
Mean	48.8125	63.9000	79.5875
Std. Deviation	2.11740	4.76166	12.89951

Note: Retention level was rated low (0-39%), Average Retention level (40-59%), High Retention level (60-100%).

Table 1 shows that the lowest retention level score from the Biology Retention Level Test (BPT) was 45% and the highest retention level score was 99%. The expected highest score was 100% while the lowest score was 0%. The mean score for academic retention level at the pretest was (M= 48.81; SD=2.12). The mean score for academic retention level at the post-test was (M=63.90; SD=4.76) and at the post-posttest was (M= 79.59; SD=12.90) respectively. This implies that there was a significant difference in the improvement (15.09%) in the academic retention level of Biology students.

Research questions 2

The results of different retention levels between male and female students after using concept mapping strategy shown in Table 2 below.

Table 2. Difference in the male and female retention level of biology students with the use of concept mapping instructional strategy to teach cell division

Academic Retention Levels	Post-test	Post-Posttest
Lowest Mark	50.00	64.00
Highest Mark	78.00	99.00
Mean	64.8250	72.4750
Std. Deviation	3.72027	11.84946

Based on Table 2, it can be seen that that the lowest mark from the Biology Retention Level Test (BPT) was 50% while the highest Mark score was 99%. The expected highest mark was 100 while the lowest mark was 0%. The mean score for retention on the post-test was (M= 64.83; SD=3.72) and the mean retention score on the post-posttest was (M=72.48; SD=11.85) respectively. This indicates that there were high retention levels among the biology students. This shows that the retention level was high at the post-posttest with a difference of (7.65).

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Research hypotheses

The result show that there is no significant difference in the pretest and posttest retention level of students taught using Concept Mapping Instructional Strategy (CMIS) and no significant influence of gender on the retention levels of students taught using (CMIS). It can be seen in Table 3 and Table 4.

Table 3. ANCOVA of the difference in the pretest, and posttest retention level of biology students with the use of concept mapping instructional strategy to teach cell division

Dependent Variable: Academic Retention level					
Source of Variation	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Covariates	2460.945[a]	73	33.712	14.599	.001
Main Effects	25.493	1	25.493	11.040	.016
Retention level at Pretest	39.424	4	9.856	4.268	.057
Retention level at post-test	151.385	9	13.762	5.960	.020
Residual	13.855	6	2.309		
Explained	2474.800	76			
Total	12510.000	77			
a. R Squared = .994 (Adjusted R Squared = .926)					

Table 3 shows that the calculated value is 11.04, and the critical table value is 3.97 at 0.05 level of significance. The F. calculated of 11.04 is greater than the critical table value of 3.97 at 76 degrees of freedom (F_{cal}=11.04 > $F_{0.05,176}$=3.97), therefore hypothesis one is rejected. This implies that there is a difference in the pretest-posttest retention level of students when concept mapping instructional strategy is used to teach Cell Division.

Table 4. T-test of difference in the male and female retention levels of biology students when concept mapping instructional strategy is used to teach cell division

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Male	26.084	49	.000	36.060	33.28	38.84
Female	14.267	26	.000	50.389	43.13	57.65

Note*:* Low Retention level (0-49%), Average Retention level (50-65%), High Retention level (66-100%)

Based on Table 4, the t-calculated value for males is 26.08, and female t-value is 14.27. The significant level is .000 at 5% (p.>0.5). Since the significant level of .000 is less than 5%. Therefore, hypothesis two is rejected. This implies that there is a significant difference in the male and female students' retention levels when concept mapping instructional strategy is used. This is in favor of male students.

The research demonstrates a noteworthy disparity in the pretest and posttest retention levels of students when the concept mapping instructional approach is implemented. Specifically, there is a substantial variation in the academic retention levels of Biology Students before and after the pretest when the concept mapping instructional strategy is utilized to instruct Cell Division. This approach notably elevated the academic retention levels of the students. The incorporation of the concept mapping instructional strategy in the teaching of Cell Division had a positive impact on the academic retention levels of the students. Furthermore, the findings reveal that Biology students taught using the concept mapping instructional strategy (experimental group) exhibited superior retention levels compared to those in the control group. This outcome

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was validated by the mean academic retention scores of the participants in the concept mapping group during the post-test (M=64.83; SD=3.72) and post-posttest (M=72.48; SD=11.85) stages respectively. These results align with previous studies by Ozomadu & Edeoga (2022) and Eze and Madu (2022) which underscore the effectiveness of concept mapping in enhancing academic retention levels among students. The findings of this study underscore that the concept mapping instructional strategy is a potent method of teaching Biology, particularly Cell Division.

The research reveals a significant correlation between gender and the utilization of the concept mapping instructional strategy on the retention levels of Biology Students, favoring males (Appaw et al., 2021). Notably, there is a substantial disparity in the retention levels of male and female Biology Students when the concept mapping instructional strategy is employed to teach Cell Division. This suggests that male biology students who were taught using the concept mapping instructional strategy exhibited enhanced and superior retention of Cell Division content compared to their female counterparts. This observation is consistent with the assertions of Toheed et al. (2017), Adeniran et al. (2018) highlight the significant improvement in mean retention scores among male students instructed with the concept mapping approach. Male students outperformed their female counterparts in terms of retention levels (Adeniran et al., 2018; Martins-Omole et al., 2016). Consequently, it can be inferred that male participants in the experimental group demonstrated a better recollection of the Cell Division concepts during the post-test compared to the female participants after two weeks. This disparity may be attributed to the male participants' enhanced ability to organize the concepts of Cell Division, thereby augmenting their retention levels compared to female students.

The study shows that there is a significant effect of CMIS on retention level of Biology students. There is a significant improvement in the retention level of students when concept mapping instructional strategy is used (Ollero, 2023). This result was linked to the use of concept mapping instructional strategy which enable Biology students to remember of Cell Division contents. The study shows that there is a significant effect of CMIS on the retention levels of students based on gender. There is an influence of gender on the use of concept mapping instructional strategy on the retention levels of Biology Students in favor of males. The study shows that there is a significant difference in the retention levels of male and female Biology Students when concept mapping instructional strategy is used to teach Cell Division.

In support of the first finding, the constructivist theory believes that learners are active participants in their learning journey; knowledge is constructed based on experiences. As events occur, each person reflects on their experience and incorporates the new ideas with their prior knowledge. Learners develop schemas to organize acquired knowledge through constant practice. For the second finding, the theoretical argument has to do with the personal effort of each learner. Clarke (2018) stated that constructivism believes in personal construction of meaning by the learner through experience and that meaning is influenced by the interaction of prior knowledge and new events. The first finding post post-test score was higher than the post-test was simply because of the effectiveness of the CMIS. This has helped learners to be able to create, organized and link some of the concepts in Cell Division which have been retained in their cognitive domain even after the training. Another contributing factor to the high retention was because the learners were able to visualized and concretize contents learnt using CMIS. Male students had higher performance than their female counterparts because male students show interest and highly motivated throughout the duration of training. They were also seen to display full concentration and pay more attention while training lasted than female students. There was a group dynamic among male students as regards their study, particularly on Cell Division with the use of CMIS.

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CONCLUSION

In light of the findings, the study suggests that there is a substantial difference in the pretest and posttest retention levels of students when utilizing the concept mapping instructional strategy. Furthermore, the study concludes that male students exhibited enhanced retention levels compared to female students. The study suggests that Biology educators should use the concept mapping instructional strategy when teaching Cell Division content in public senior secondary schools, as this approach can significantly improve retention levels of biology students. The research results obtained implied that Biology teachers must prioritize the use of CMIS when teaching Biology contents of Cell Division. Biology teachers must pay more attention to students with low retention in Cell Division. The use of CMIS to teach Cell Division must be accorded with utmost importance for female students. It is suggested that there are implications from the research results obtained that, Biology teachers should use Concept Mapping Instructional Strategy (CMIS) to teach students with low retention. This would enhance students' retention levels in the Biology content of the Cell Division. It is also suggested that Biology teachers should use CMIS to teach female students with lower retention levels, thereby enhancing their overall Biology retention.

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