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EFFECTS OF MNEMONIC INSTRUCTIONAL STRATEGY ON UNDERGRADUATE STUDENTS' ACHIEVEMENT AND RETENTION IN TOPOLOGY IN ONDO STATE, NIGERIA

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Abstract

This study investigated the effects of mnemonic instructional strategy on undergraduate students' achievement and retention in topology. A quasi-experimental pre-test, post-test, control-group design with a delayed retention test was adopted. The population comprised 210 mathematics-related undergraduates, while the sample consisted of 75 Level 200 students drawn from two universities in Ondo State through a multistage sampling procedure. The experimental group (n = 35; 15 males and 20 females) was taught topology with mnemonic strategies, including acronyms, symbolic cues, diagrams, visualization and associative techniques, while the control group (n = 40; 19 males and 21 females) received conventional lecture-based instruction. Data were collected only with the Mathematics Topology Achievement Test (MTAT), which measured achievement and delayed retention in sets, topological spaces, continuity, compactness and connectedness. Descriptive statistics, ANCOVA and Welch's independent-samples t-test were used for analysis at the .05 level of significance. Findings showed that the mnemonic group recorded a higher post-test mean score (M = 73.29, SD = 10.84) than the lecture-based group (M = 49.80, SD = 26.76). The mnemonic group also demonstrated stronger delayed retention (M = 56.43; 77.00% retained) than the lecture-based group (M = 14.12; 28.35% retained). The study concluded that mnemonic instructional strategy improves achievement and long-term retention in topology and recommended its integration into undergraduate mathematics instruction.

Keywords: Mnemonic Instructional Strategy, Lecture-Based Method, Achievement, Retention, Topology, Undergraduate Mathematics

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

Introduction

Students' academic success depends largely on their understanding of classroom concepts and their ability to retain and recall learned information over time. Learning is incomplete if knowledge cannot be stored, retrieved and applied when needed. In mathematics, this need is even more important because later concepts usually depend on earlier definitions, theorems, notations and procedures. A student who cannot recall the meaning of an open set, compactness or connectedness is unlikely to follow more advanced proofs in topology.

Memory is therefore central to meaningful learning. Cognitive psychology explains that learners remember better when new information is encoded in an organised, meaningful and retrievable form. Mnemonic strategies provide such support because they help learners connect unfamiliar content with familiar words, images, diagrams, phrases or symbols. Instead of treating abstract definitions as isolated statements to be memorised mechanically, mnemonics allow students to build cues that aid recognition, recall and application (Dunlosky et al., 2013; Scruggs & Mastropieri, 2000).

The term mnemonic derives from the Greek word mnemonikos, meaning relating to memory. In educational practice, mnemonic devices include acronyms, acrostics, keywords, imagery, chunking, rhythm, symbolic coding and associative mapping. Manalo et al. (2004) showed that mnemonic support can improve learning of unfamiliar symbolic materials, while Wolgemuth et al. (2008) reported positive academic outcomes for mnemonic interventions across learning contexts. Such findings suggest that mnemonics are relevant to subjects where students must remember difficult terms and use them accurately.

Mathematics occupies a central place in scientific, technological and national development. It supports reasoning in engineering, computing, economics, data science and the physical sciences. However, mathematics learning is often weakened when instruction is dominated by lecture-based presentation and when students are not actively guided to organise abstract ideas for long-term recall. Active learning research in science, engineering and mathematics indicates that students learn more when they participate in activities and discussions rather than passively receiving information (Freeman et al., 2014).

Topology is one of the undergraduate mathematics courses in which memory, abstraction and proof-based reasoning intersect. It studies properties of space that remain unchanged under continuous deformation, such as stretching, bending or twisting without tearing or gluing. Core concepts such as open sets, closed sets, neighbourhoods, continuity, compactness and connectedness are definition-driven. Students must not only recall definitions but also recognise how definitions operate in proofs and examples. Research on advanced mathematical thinking shows that undergraduate students often

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

struggle when they move from computational mathematics to formal definitions, logical structure and proof construction (Moore, 1994; Tall, 1991; Tall & Vinner, 1981).

These challenges make topology a suitable context for mnemonic instruction. Mnemonic strategies can help students compress complex definitions into memorable cues, link symbolic expressions with visual representations, and remember the sequence of proof steps. For example, diagrams may help students connect continuity with the preservation of neighbourhood structure, while associative phrases may help them recall that compactness concerns open covers and finite subcovers. Such strategies do not replace mathematical proof; rather, they provide cognitive bridges that help students retrieve the formal ideas needed for proof construction.

Previous studies have reported positive effects of mnemonic instruction in mathematics-related learning contexts. Akinsola and Adeyemo (2014) found that mnemonic and prior-knowledge strategies improved students' achievement in mathematics, while Padernal (2023) reported that mnemonic-aided instruction improved maritime students' performance in calculus. In undergraduate mathematics education, research on proof and advanced mathematical thinking also shows that students need support in coordinating definitions, examples, symbols, diagrams and proof strategies (Moore, 1994; Weber, 2001). However, the available literature gives limited attention to the use of mnemonic strategies in undergraduate topology, particularly in Nigerian universities. This gap provides the basis for the present study.

This study therefore investigated the effects of mnemonic instructional strategy on undergraduate students' achievement and retention in topology. The focus on achievement shows whether the strategy improves immediate learning outcomes, while the focus on retention shows whether students can preserve and recall topology concepts after the main teaching period.

Statement of the Problem

Topology is a critical area of advanced mathematics because it supports further study in analysis, geometry, algebraic topology, computer science, physics and engineering. Despite its importance, many undergraduates perceive topology as abstract and difficult. They often struggle to remember precise definitions, distinguish closely related concepts, and apply theorems correctly in proofs.

Conventional lecture-based instruction provides useful explanation of definitions and theorems, but it may not sufficiently support students' active encoding and retrieval of abstract mathematical information. When students listen passively, they may understand a concept during class but fail to recall it during problem solving or later assessments. This weak retention can lead to low achievement, poor confidence and reduced interest in advanced mathematics.

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

Although studies have shown that mnemonic strategies can improve memory and achievement in other subjects and some areas of mathematics, there is limited empirical evidence on their effectiveness in teaching undergraduate topology. The problem addressed in this study is therefore whether mnemonic instructional strategy can improve university students' achievement and retention in topology when compared with conventional lecture-based instruction.

Purpose of the Study

The purpose of this study was to determine the effects of mnemonic instructional strategy on undergraduate students' achievement and retention in topology in Ondo State, Nigeria. Specifically, the study sought to:

1. examine the difference in the post-test achievement scores of students taught topology with mnemonic instructional strategy and those taught with the lecture-based method; and
2. determine the difference in the retention scores of students taught topology with mnemonic instructional strategy and those taught with the lecture-based method.

Research Questions

1. What difference exists between the post-test achievement scores of students taught topology with mnemonic instructional strategy and those taught with the lecture-based method?
2. What difference exists between the retention scores of students taught topology with mnemonic instructional strategy and those taught with the lecture-based method?

Research Hypotheses

The following null hypotheses were tested at the .05 level of significance:

1. There is no statistically significant difference between the adjusted post-test achievement mean scores of students taught topology with mnemonic instructional strategy and those taught with the lecture-based method after controlling for pre-test performance.
2. There is no statistically significant difference between the retention mean scores of students taught topology with mnemonic instructional strategy and those taught with the lecture-based method.

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

Methodology

The study adopted a quasi-experimental pre-test, post-test, control-group design with a delayed retention test. The design was appropriate because intact classes were used and random assignment of individual students was not feasible. Two groups participated in the study: an experimental group taught with mnemonic instructional strategy and a control group taught with the conventional lecture-based method.

The population comprised 210 undergraduate students offering mathematics-related courses in two universities in Ondo State. The sample consisted of 75 Level 200 students drawn from the same two universities through a multistage sampling procedure. At the first stage, the two universities were purposively selected because they offered the relevant undergraduate topology course. At the second stage, one intact Level 200 class was selected from each university. At the third stage, the two intact classes were assigned by balloting: one class became the experimental group and the other became the control group. The experimental group consisted of 35 students, comprising 15 males and 20 females, while the control group consisted of 40 students, comprising 19 males and 21 females.

The treatment involved the implementation of mnemonic instructional strategy. Students in the experimental group were taught selected topology concepts using acronyms, symbolic cues, diagrams, visual imagery, concept association and chunking. The lessons focused on key topics such as sets, topological spaces, open and closed sets, continuity, compactness and connectedness. The strategy was used to help students encode definitions, identify key properties and recall proof steps. The control group was taught the same topics through the conventional lecture-based method without planned mnemonic enhancement.

One instrument was used for data collection: the Mathematics Topology Achievement Test (MTAT). The MTAT measured students' achievement and delayed retention in topology. It consisted of multiple-choice and short-answer items covering sets, topological spaces, continuity, compactness and connectedness. The instrument was administered as a pre-test, post-test and delayed retention test. The pre-test measured students' topic-specific baseline knowledge before treatment, the post-test measured achievement after treatment, and the delayed retention test measured recall of the taught topology concepts after the intervention period. Students' general academic records or previous semester averages were not used as pre-test or post-test data, because such records are not topic-specific measures of topology concepts such as sets, compactness and connectedness.

The MTAT was subjected to face and content validation by experts in mathematics education and educational measurement. The validators examined the clarity, relevance, coverage and difficulty level of the items. A pilot test was conducted, and a reliability

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

coefficient of .70 was obtained using Cronbach's alpha, which was considered acceptable for the study.

Data collected from the MTAT were analysed using descriptive and inferential statistics. Mean and standard deviation were used to answer the research questions. Mean gain was calculated by subtracting the pre-test mean from the post-test mean. For retention, the delayed retention mean was treated as the main retention outcome. To clarify the durability of learning, score decrease and percentage retained were also computed as descriptive indicators. Score decrease was calculated by subtracting the delayed retention mean from the post-test mean, while percentage retained was calculated by dividing the delayed retention mean by the post-test mean and multiplying by 100. A smaller score decreases and a higher percentage retained indicated stronger retention. ANCOVA was used to test the difference in post-test achievement after controlling for pre-test scores. Welch's independent-samples t-test was used to compare the delayed retention scores because the group sizes and variances were unequal. All hypotheses were tested at the .05 level of significance.

Results

Research Question 1: *What difference exists between the post-test achievement scores of students taught topology with mnemonic instructional strategy and those taught with the lecture-based method?*

Table 1: Students' achievement scores in topology by instructional method

Group	N	Pre-test M	Pre-test SD	Post-test M	Post-test SD	Mean gain
Mnemonic strategy	35	9.60	4.15	73.29	10.84	63.69
Lecture-based method	40	9.50	3.14	49.80	26.76	40.30

Note. Mean gain = post-test mean - pre-test mean.

Table 1 shows that the two groups had nearly equivalent pre-test mean scores before treatment, suggesting comparable baseline knowledge of topology. The experimental group recorded a pre-test mean of 9.60, while the control group recorded a pre-test mean of 9.50. After treatment, the experimental group obtained a post-test mean score of 73.29, compared with 49.80 for the lecture-based group, a difference of 23.49 points. The mean gain for the experimental group was 63.69, while the control group recorded a mean gain of 40.30. The 23.39-point advantage in mean gain indicates that mnemonic instruction produced a stronger improvement in achievement than lecture-based instruction, particularly because the two groups started from almost the same baseline.

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

Research Question 2: *What difference exists between the retention scores of students taught topology with mnemonic instructional strategy and those taught with the lecture-based method?*

Table 2: Delayed retention scores in topology by instructional method

Group	N	Post-test M	Post-test SD	Delayed retention M	Reten-tion SD	Score decrease	Retained (%)
Mnemonic strategy	35	73.29	10.84	56.43	9.35	16.86	77.00
Lecture-based method	40	49.80	26.76	14.12	8.23	35.68	28.35

Note. *Score decrease = post-test mean - delayed retention mean. Percentage retained = delayed retention mean divided by post-test mean x 100. These descriptive indicators clarify the durability of learning; the delayed retention mean remains the main retention score.*

Table 2 shows that students taught with mnemonic instructional strategy retained substantially more topology content than those taught with the lecture-based method. The experimental group declined from a post-test mean of 73.29 to a delayed retention mean of 56.43, representing a score decrease of 16.86 and 77.00% of post-test learning retained. In contrast, the lecture-based group declined from a post-test mean of 49.80 to a delayed retention mean of 14.12, representing a larger score decrease of 35.68 and only 28.35% retained. The smaller decrease and higher percentage retained in the mnemonic group show that the strategy did not only improve immediate achievement but also supported more durable recall of abstract topology concepts over time.

Hypothesis 1: *There is no statistically significant difference between the adjusted post-test achievement mean scores of students taught topology with mnemonic instructional strategy and those taught with the lecture-based method after controlling for pre-test performance.*

Table 3: ANCOVA summary for post-test achievement scores in topology

Source	Type III SS	df	Mean square	F	P
Corrected model	36,803.018	2	18,401.509	81.69	< .001
Intercept	71,215.378	1	71,215.378	316.14	< .001
Pre-test	1,465.331	1	1,465.331	6.51	.013
Instructional method	35,337.687	1	35,337.687	156.87	< .001
Error	16,218.982	72	225.264		
Total	239,025.000	75			
Corrected total	**53,022.000**	**74**			

Note. $R^2 = .694$; *Adjusted* $R^2 = .685$.

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

Table 3 shows that instructional method had a statistically significant effect on students' post-test achievement in topology after controlling for pre-test achievement, $F(1, 72) = 156.87$, $p < .001$. The null hypothesis was therefore rejected. This means that the higher achievement of the experimental group was not merely due to initial differences in pre-test scores. Approximately 68.5% of the adjusted variance in post-test achievement was explained by the model, indicating a strong treatment effect.

Hypothesis 2: *There is no statistically significant difference between the delayed retention mean scores of students taught topology with mnemonic instructional strategy and those taught with the lecture-based method.*

Table 4: Welch independent-samples test for delayed retention scores

Group comparison	Mean difference	SE	t	Df	p	Cohen's d
Mnemonic strategy vs. lecture-based method	42.31	2.05	20.67	68.34	< .001	4.82

Note. The Welch test was used because the group sizes and variances were unequal.

Table 4 shows a statistically significant difference in delayed retention scores between the two groups, $t(68.34) = 20.67$, $p < .001$. The null hypothesis was rejected. This means that students taught with mnemonic instructional strategy remembered significantly more topology content during the delayed retention test than those taught with the lecture-based method. The very large effect size (Cohen's $d = 4.82$) further indicates that the mnemonic instructional strategy had a strong practical effect on students' retention of topology concepts.

Discussion of Findings

The findings showed that students taught topology with mnemonic instructional strategy achieved higher post-test scores and retained more content than students taught with the lecture-based method. This result is not merely a confirmation that mnemonics improve memory; it also shows why memory-supportive instruction is particularly useful in topology. Topology is a definition-centred and proof-based area of undergraduate mathematics. Students must remember precise statements such as open set, neighbourhood, continuity, compactness and connectedness, and must also know when and how to use those statements in symbolic arguments. Mnemonic cues therefore helped students to organise the formal language of topology into retrievable patterns that could support understanding, recall and proof construction.

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

The effect of the strategy can be explained by the nature of topology itself. In many computational mathematics topics, students may rely on procedures and worked examples. In topology, however, the learner must constantly move between formal definitions, diagrams, symbolic notation, examples, counter-examples and logical implications. This movement is cognitively demanding. The mnemonic strategy made this movement easier by linking abstract ideas with verbal cues, visual images and symbolic associations. For instance, compactness becomes easier to retrieve when students remember its relationship with open covers and finite subcovers, while continuity becomes clearer when students link the idea to preservation of open-set structure or neighbourhood behaviour. Thus, mnemonics were effective because they served as conceptual anchors rather than as isolated memory tricks.

This interpretation is consistent with international research on undergraduate mathematics education. Tall and Vinner (1981) showed that students often experience tension between the formal concept definition and their personal concept image. Moore (1994) also reported that undergraduates struggle when moving from computational mathematics to formal proof. Weber (2001) further found that students may know relevant mathematical facts but still fail to construct proofs because they lack strategic knowledge about how to use those facts. The present study agrees with these findings because the experimental group appeared to benefit from a strategy that helped them recall definitions and connect them to proof-related tasks. In this sense, mnemonic instruction may reduce the gap between knowing a definition and being able to use it productively.

The findings also compare favourably with studies that focus specifically on topology and visual reasoning. Gallagher and Engelke Infante (2022) reported that visual representations can support undergraduates in identifying key ideas during topology proof construction, although diagrams are useful only when students actively extract mathematical information from them. Similarly, Kontorovich and Greenwood (2024) showed that students' proofs in a topology classroom can become more formal and elaborate when proof construction is supported through structured classroom activity. The present study extends these international findings by demonstrating quantitatively that mnemonic-supported instruction, which included diagrams, symbolic cues and associative techniques, can improve both achievement and delayed retention in topology. The result is also related to Padernal's (2023) study in undergraduate calculus, where mnemonic-aided instruction improved students' performance after intervention. However, the present study differs from calculus-based evidence because topology demands more sustained engagement with abstraction, formal definitions and non-computational proof. The positive outcome in this study therefore suggests that mnemonic instruction is not limited to procedural mathematics. It can also support

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

advanced mathematical reasoning when the cues are tied to meanings, examples, definitions and proof steps.

The retention finding is especially important. Students taught with mnemonic strategy recorded a higher delayed retention mean, a smaller decrease from post-test to retention test and a higher percentage of retained learning. This suggests that the strategy did not only assist immediate performance but also created retrieval cues that remained useful after the teaching period. This is consistent with cognitive learning principles that durable learning depends on meaningful encoding and later retrieval (Dunlosky et al., 2013). It also reflects the broader evidence that active learning improves outcomes in science, engineering and mathematics because students participate more directly in constructing meaning (Freeman et al., 2014).

Rupnow and Fukawa-Connelly (2024) reported that mathematicians regard understanding of concepts and definitions in proof-based courses as involving more than repeating formal statements; it includes unpacking terms, relating definitions to examples and using concepts in proofs. The present study supports this position. The mnemonic strategy was effective because it helped students remember definitions while also linking them to diagrams, examples and proof tasks. Therefore, the value of mnemonic instruction in topology lies in helping students develop usable recall--the kind of recall that supports reasoning, not rote memorisation alone.

Nevertheless, mnemonic instruction should not be treated as a substitute for rigorous mathematical reasoning. Its strength lies in supporting the recall and organisation of the conceptual materials needed for reasoning. If used superficially, mnemonics may encourage students to memorise phrases without understanding. For topology, the most productive use of mnemonics is therefore to combine memory cues with examples, counter-examples, diagrams, guided proofs, group discussion and problem-solving activities. In this way, mnemonic instruction can serve as a bridge between memory, conceptual understanding and proof competence in undergraduate mathematics.

Conclusion

This study concluded that mnemonic instructional strategy has a significant positive effect on undergraduate students' achievement and retention in topology. Students exposed to mnemonic instruction performed better in the post-test and retained more knowledge in the delayed retention test than their counterparts taught with the lecture-based method. The findings show that mnemonic strategies can strengthen students' understanding and recall of abstract concepts such as open sets, continuity, compactness and connectedness.

The practical implication is that undergraduate mathematics teaching should not depend solely on lecture-based explanation of definitions and theorems. Lecturers can improve

EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]

learning outcomes by incorporating structured memory supports such as acronyms, symbolic cues, diagrams, imagery and concept associations. Such approaches are especially useful in abstract courses where students must remember precise definitions and use them in proof construction.

The study was limited by the use of intact classes and a relatively small sample drawn from two universities. The findings should therefore be generalised cautiously. Future studies should use larger samples across more institutions, examine longer retention intervals, and investigate how mnemonic instruction interacts with variables such as students' prior achievement, mathematical anxiety, motivation and proof competence.

Recommendations

1. Mathematics lecturers should integrate mnemonic instructional strategies into the teaching of topology and other abstract undergraduate mathematics courses. Acronyms, symbolic cues, diagrams, visual imagery and associative techniques should be used to support recall of definitions and proof steps.
2. Mnemonic instruction should be combined with examples, counter-examples, guided proofs and problem-solving activities so that students do not merely memorise cues but also understand and apply the underlying concepts.
3. Departments of mathematics and mathematics education should organise workshops to train lecturers on how to design and use mnemonic strategies for advanced mathematical topics.
4. Curriculum planners should include memory-supportive and learner-centred instructional strategies in teacher education programmes so that future mathematics teachers can support both understanding and retention.
5. Academic advisers and counsellors should encourage students who struggle with abstract mathematics to adopt structured study techniques, including mnemonic cueing, concept mapping and retrieval practice.
6. Further research should compare mnemonic instruction with other active learning approaches in topology, such as inquiry-based learning, flipped classroom instruction and technology-supported visualisation.

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EDITOR-IN-CHIEF
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EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]