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Instructional Technology Strategy and Cognitive Load Reduction: Implications for Students Understanding of Biology Concepts in Makurdi Metropolis of Benue State

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Abstract

This study investigated Instructional Technology and Cognitive Load Reduction: Implications for Students' Understanding of Biology Concepts in Makurdi Metropolis, Benue State. The study adopted a quasi-experimental research design using a non-equivalent control group pretest–posttest format. Two research questions were answered, and two hypotheses were tested at the 0.05 level of significance. The population comprised all Senior Secondary School III (SSS III) Biology students in Makurdi Metropolis. A sample of 186 students (125 males and 61 females) from intact classes was selected through a multistage sampling procedure. The Cognitive Load Measurement Scale (CLMS) was adapted for the study and validated by three experts. The instrument was trial-tested on 30 students, and its reliability was determined using Cronbach's Alpha, which yielded a coefficient of 0.87. Data were analyzed using descriptive statistics, including mean and standard deviation, while Analysis of Covariance (ANCOVA) was used to test the hypotheses. The findings revealed a significant difference in the mean cognitive load ratings of students taught Biology concepts using Instructional Technology Strategies (ITS) and those taught using the traditional teaching method, with ITS proving more effective in reducing cognitive load. The study also found a significant difference in the mean cognitive load ratings of male and female students taught using ITS, in favour of the male students. The study concluded that the use of Instructional Technology Strategies enhances the teaching and learning of Biology concepts by reducing students' cognitive load. It was therefore recommended that the Ministry of Education, curriculum developers, and policymakers integrate instructional technology into Biology lesson design and classroom instruction.

Keywords: Biology, Cognitive Load, Gender, Instructional Technology, and Strategy

Introduction

The ever-changing need of having an inclusive Biology classroom, where all the students can learn together, either at an individual pace or a close pace, and having similar access to learning opportunities, has led researchers to a critical study on the most preferred, relevant and suitable means of teaching Biology lessons to the students in the classroom. This is because Biology which is one of the fundamental science subjects in Nigeria Senior Secondary Schools (SSS), is very pivotal in helping students understand their body assembly, role and the inter-relatedness of the body system. Biology content also offers students opportunity to learn about the living and non- living things around them (Kpiranyam, Enemarie, & Fakaa, 2024).

Biology also serves as the basses for which students are placed to study subjects like Biology Education, Medicine, Nursing, Food science among others in the higher institution of learning. Because of this criticality of Biology subjects, experts are consistently engaging in research to assess strategies for instructional delivery in biology. The research has resulted in the emergence of varying instructional strategies that can accommodate other resources which

the teacher can use to enhance the process of instructional delivery in the classroom, one of such strategy that may accommodate this teaching innovation is instructional technology.

Instructional technology strategy (ITS) entails instructional delivery requiring the use of information communication tools (ICT) within the learning process. ITS is the systematic way of planning, designing, executing, and assessing the total process of instructional delivery and knowledge acquisition based on specific instructional objectives, using available human (the teacher) and non-human (technology) elements to foster learning outcome (Salawu &Oyekola, n.d). Nwaokolo (2023) defines ITS as the orderly and innovative combination of "invention" (technologies) and "inventor" (teacher) with specific subject content to stimulate instructional delivery process within and across disciplines. ITS is also viewed as the deliberate teacher's effort to creatively infuse technology into the process of instructional delivery through intentional searching, planning, organizing, and aligning instructions in a way that allowance is given to technology usage in the classroom so that the comprehension of the learners is enhanced (Egielewa *et.al.*, 2022).

The University of Zambia (2025) defines Instructional Technology Strategy (ITS) has formulation and practice of designs, creative utilization, management and evaluation of processes and technological resources for learning. In the words of Kumander, (2020) ITS handles issues relating with systematic designing, and delivering of technological-driven instructions in specific area which can be for both online and offline classroom learning experiences. The use of ITS in the classroom has birthed a lot of advantages to the teaching and learning processes, it aids in motivating and arresting pupils' attention, increasing learners' curiosity and consciousness and thereby providing a sound environment for a realistic and enjoyable teaching and learning atmosphere (Salawu &Oyekola, n.d; Anil, 2024). Anazifa, 2022 reported that ITS helped at adding value to learning by making abstract parts of the curriculum available that other teaching methods do not. ITS also gives rooms to helping students whose learning difficulty has been identified by using assistive technology devices, allowing them to access the lessons in a simpler form (Asare & Parker, n.d). Through ITS, opportunity is provided for Biology teachers to design their lessons in an innovative and engaging way (Nwaokolo, 2023). ITS also gives students the opportunity to access real time information of the concept thought which can lead to meaningful learning, rather than rote learning.

In a study by Mahadewi *et al.* (2018), reducing Students' CL by Developing Rotation Learning in Blended Setting was examined in Ganesha, Indonesia. The study tested the effect of the innovative delivery learning strategy on students taking courses in a blended setting, The results showed that the innovative delivery learning strategy was effective in reducing students' CL. There are some gaps between the study and the present study that the present study would like to fill; the reviewed study adopted developmental research design while the present study is quasi-experimental research. The reviewed study (RS) focusses on Rotation Learning in Blended Setting while the present study (PS) focuses on the use of ITS in teaching and learning of Biology, the method of data analysis to be used by the PS is ANCOVA as against the t-test used in the RS.

Ezechi (2021) Examined the Problems of Teaching and Learning Genetics in Secondary School. Survey research design was used in carrying out the study, a structured questionnaire consisting of 20 items raised was used for data collection. The correlation coefficient obtained using. The findings revealed that the areas of Genetics teachers and students find difficult to teach and learn were Genetic crossing, structure of DNA and RNA among others. There were still gaps that existed that this PS checked. One of which was the use of innovative teaching methods in teaching Biology in the classrooms, ITS which the PS employed to observe any effective change in Biology students'. The PS also consider students CL which the RS did not consider.

Burkes (2007) worked on Applying CLT to the design of online learning in Toulouse Graduate School, North Texas. Students in three different courses were measured on both learning performance and perceptions of mental effort to see if there were any statistically significant differences. The study utilized a quasi-experimental post-test-only design, contrasting modified and unmodified instructional lessons. On measures of CL, no statistically significant differences were found. The focus of the PS is on SS III student of Biology in Makurdi Metropolis, while the RS scope is University students' biology in North Texas. Before the effective utilization of ITS in the biology classroom, with the hope of reducing students CL, the biology teacher must of consider the following;

The learning and performance objectives (Spector, 2016): The biology teacher should consider her desired learning outcomes and consider if the usage

of technology in the lesson will aid the achievement of the stated goals.

The learner's age and abilities: The teacher also considers the students' maturity age wise and what they can do; this will help in determining the extent to which technology can be integrated in the lesson (Micheal-Aondoaseer *et.al 2023*). Just like how pupils are not taught all they need to know about living things in nursery school, so also is the use of technology in the classroom. The learners' age and ability determine, to a great extent, the type of technology tools to be used (Phani & Laxmi 2024).

Creating materials and activities for learning: Anil, (2024) noted that when designing IT, the teacher would have to check the media that will allow the student to interact with the lesson and not become passive since a paradigm shift has occurred which places learning as an active process, which means students are to be involved in the process of learning. Researchers in this field have explored the different ways in which technology can be effectively integrated into the classroom, it has been suggested that technology will make a great impact on teaching and learning if it is used while the teacher is present in the class to guide the process (Hensley, 2020). It is also possible that the use of ITS for instructional delivery could help reduce students CL.

Before a new knowledge can be acquired during a learning period, the students brain undergoes some effort in order to process what is been taught, sometimes, the working memory (WM) is challenged with the demand to process some of these new concepts. This extra demand on the WM is what leads to CL especially when the students do not have a prior knowledge of the concepts been taught. Kalyuga and Liu (2015) defines CL as WM resources needed for completing a learning task or activity by students with a specific level of prior knowledge. CL is the brain workload when processing any incoming new information (Chandler &Sweller, 1991; Multu*et al.*, 2022). The ease with which learning content may be processed in WM is a the major concern of the CL Theory (Swelle*et al.*, 1998). When learners receive new information, their sensory memory immediately takes it, the information is then transferred to the WM, if the processed information has a background or schema in the long-term memory of the student, the information is reinforced without any difficulties but if the processed information is new, the learner is then faced with the challenge of processing it from the WM to long- term memory. At this point, the learner has to go through some brain work; as he does that, extra mental demand is being placed on the learner's cognition (Kpiranyam, &Enemarie, *etal* 2024). This whole process is what leads to CL.

Several researchers had worked on the concept of CL, Yi-Hung (2018) in his research discover that CL occurs across varying educational level, from lower basic schools to higher institution of learning. Multu*et al* (2022); Akinbadewa (2015) and Burkes (2007) all noted in different studies that CL affects students' performance because proper understanding of concept taught is not gotten by the students and new schema is not formed due to the limited WM of students and the different form of CL students are going through. Sweller (2016); Mehrotra and Gunalakshmi (2020); and Houichi and Sarnou (2020) identified three different types of CL which include:

Intrinsic cognitive load (ICL), it has to do with the interactivity level of the information available to students to process in the content of learning and their ability to learn; it deals mainly with the nature of the instruction that is being learnt (Mehrotra & Gunalakshmi, 2020). ICL is shown in the extent to which various information in the lesson content of the teacher interact. It is possible to understand some lessons or information as an individual entity, while some other lessons are deeply integrated this is because the lessons do not interact or relate, therefore, it would be safe to say ICL is determined by the blend ability or difficulty of the lessons to be learnt. Kalyuga and Liu (2015) believes that ICL is the load that is relevant to achieving the intended learning goals.

Extraneous cognitive load (ECL), This is the CL that occurs during the process of instructional delivery, when teachers add unnecessary information to the content of the lesson they are delivering to the learners, the less important information leads to students having high CL; which is known as ECL (Oladele, 2019).

When ECL occurs, it is believed to have been caused by high level of content interactivity, in this case, the content interactivity is introduced by inappropriate instructional designs that unnecessarily increase the interacting content that learners must process (Yingying, 2018). The teacher must pay attention to the instructional design that would be used for a lesson, since ECL is majorly created based on how the teacher presents the lesson, what he did and did not do (Swelle*et al., 2019*). and Germane cognitive load (GCL**)**, occurs when students successfully learn new concept from lessons that are taught in the classroom,

and the new concept are transferred into their Long-Term Memory (LTM), which is activated by challenging the student's brain to apply effort towards understanding the material (Houichi and Sarnou, 2020). Seedwell (2019) sees GCL as the energy imposed by the learning processes on learners, which arises from bringing back relevant information from the LTM of the brain to enhance new information elements.

GCL can be sustained in the biology classroom while ICL and ECL reduced if the biology teacher approaches the teaching in a different form. Kpiranyam, *et.al* (2024); Toh, and Tasir (2024), observed that a major way of reducing students CL in biology classroom is a change in teachers' instructional strategy to an innovative strategy that could possibly accommodate the use of technology. Students CL has also been related to gender; though gender patterns in literatures are nuanced.

Gender is the state of been male or female according to the societal believe and norms. Some researchers believe gender does not significantly influence students' performance or CL (Oladele, 2019; Musa et al., 2025; Achor et al., 2024), while Akinbadewa, (2015); Michael-Aondoaseer et.al (2025) found that the complex nature of biology makes female students develop high CL. Arising from these discussions and to fill gap in the literature, this study examined the possibility of reducing students of biology CL through Instructional technology strategy (ITS) in Makurdi, Benue State.

Research Questions

1. What is the difference between the mean cognitive load ratings of students taught Biology with ITS and those taught with the Traditional method?
2. What is the difference between the mean cognitive load ratings of male and female students taught Biology using ITS in Makurdi metropolis of Benue State, Nigeria?

Hypotheses

1. There is no significant difference between the mean cognitive load ratings of students taught Biology using ITS and those taught with the traditional method.
2. There is no significant difference between the mean cognitive load ratings of male and female students taught Biology using ITS.

Research Method

The study adopted a Quasi-experimental design, mainly, pre-test post-test non-equivalent non-randomized control group. The population comprised of 6,898 SS III students across the 21 public and co-educational Secondary Schools in Makurdi metropolis of Benue State in the 2024/2025 academic session (Benue State Teaching Service Board, 2024). Sample size of 186 SSIII students offering Biology was drawn from four intact classes selected using multi-stage sampling using the following procedure; the use of different sampling methods at each stage of the study: A purposive sampling technique was used to select the schools that were involved in the study. In each of the four schools selected, simple random sampling was used to select one intact class, two were designated experimental based on the availability of ICT resources in the school while the other two; for control. The experimental groups were taught with BLIS while the control groups were taught using the lecture method and randomly assigned to experimental and control group. the instrument for the study is Biology Cognitive Load Rating Scale (BCLRS).

The BCLRS was adapted from Leppink, Paas, *et.al* (2013), the Adapted version comprised of two sections. Section A sought the name of the respondents' school and gender. Section B is made up of 10 items related to the content learnt during the biology lessons including the ITS adopted for the lesson / concept and a questionnaire comprising an options scale 0-10 in which students were required to pick one number in response to each item on the scale, 0 indicates not at all the case, and 10 which means completely the case. The items were weighted as 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10. 5 is the mid-point of the item, any number above 5 is on the negative side which means high CL and any one below or exactly 5 is on the positive side which means low CL. This instrument was administered to the students before and after the control lessons and experimental treatment**.**

The BCLRS was validated by three experts, one science education expert from College of Education Akwanga, one measurement and evaluation expert in the Department of Educational Foundations and General Studies from Joseph Sarwuan Tarka University, Makurdi and a Biology Teacher from Calvary Arrows College Gboko. The experts thoroughly scrutinized the instruments and lesson plans to ensure they were appropriate, unambiguous, relevant, and capable of measuring what they were designed to measure. Observations and corrections by the experts

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were considered and all errors were corrected. BCLRS was trial tested on 30 students offering Biology in an intact class to determine the reliability. Reliability of the instruments was done using the Cronbach Alpha method which gave reliability coefficients of 0.87. These values indicate that the instruments have high internal consistency. Thus, the instruments were adjudged to be reliable. The researchers sought permission from the principals of the four sampled schools. Four qualified Biology teachers with B.Sc (Ed.) and at least four years of teaching experience from the sampled schools were used as research assistants. The study lasted for six weeks. In the first week, before the treatment, the research assistants were trained afterwards pre-tests using BCLRS were administered to the experimental group and the control group. Treatment lasted for four weeks, the experimental group was taught Biology using an instructional technology strategy while the control group was taught the same topics using traditional strategy. The lesson plans for teaching the experimental group and control group lasted for eighty minutes (double period) for each week. By the sixth week, BCLRS was re-administered in the experimental group and control group. To answer research questions, mean and standard deviation were used while the null hypotheses were tested at P 0.05 level of significance using Analysis of Covariance (ANCOVA). The decision rule for rejection or otherwise of the hypotheses is based on p-value and alpha value, an hypothesis of no significant difference will not be rejected for any hypothesis whose p-value is greater than the alpha value of 0.05 ($p > 0.05$ while it will be rejected for any hypothesis whose p-value is equal to or less than the alpha value of 0.05 ($p \leq 0.05$). To control extraneous variables in the course of the experiment; the researcher prepared different Lesson Plans for the two groups which were used by the research assistants; this was done to reduce teachers' influence on the lesson preparation. The effect of pre-test and post-test on the students was controlled by giving a period of five weeks before the post-test, this period was adequate to disallow the pre-test from affecting the post-test since the student were exposed to the lessons within the four weeks and the post-test took place at the sixth week of the research.

Results

In line with the earlier stated research questions and hypotheses, the results are here by presented.

Table 1 Mean and Standard Deviation of CL Ratings of Students Taught Biology with Traditional method and Those Taught with ITS.

Group	N	Pre-BCLMS		Post-BCLMS		Mean Reduction
		$\bar{X}$	SD	$\bar{X}$	SD	
Traditional	101	6.81	2.50	4.99	1.85	1.82
ITS	85	7.50	2.42	5.80	1.52	1.70
Mean Diff		0.69		0.81		0.12
Total	186					

In Table 1, the result shows the mean CL ratings of students taught Biology with BLIS and those taught with traditional method in Makurdi Metropolis. The result showed that the students taught Biology with the traditional method had a mean score of 6.81 and 4.99 in the pre-BCLMS and post-BCLMS, with a corresponding SD of 2.50 and 1.85 respectively. The students taught Biology with ITS had a mean of 7.50 and 5.80 in the pre-BCLMS and post-BCLMS, with a corresponding SD of 2.42 and 1.52 respectively. It was further shown in Table 1 the CL mean reduction values of 1.82 and 1.70 for students taught biology with ITS and those taught with Traditional method. The mean CL reduction is 0.12 in favour of the student's taught biology with ITS.

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Table 2: ANCOVA Result of CL Ratings of Students Taught Biology with ITS and Those taught with traditional method.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	37.919[a]	2	18.960	6.808	.001	.069
Intercept	692.676	1	692.676	248.708	.000	.576
PREBCLMS	7.356	1	7.356	2.641	.106	.014
METHODS	34.223	1	34.223	12.288	.001	.063
Error	509.672	183	2.785			
Total	6032.000	186				
Corrected Total	547.591	185				

In Table 2, the result of ANCOVA shows that the F(1,183) = 12.288, P-value of 0.001<0.05 level of significance. This shows that the test is significant, the null hypothesis of no significant difference is rejected. The result implies a statistically significant difference in the mean CL ratings of students taught Biology with ITS and those taught with traditional method. It implies that students taught Biology using ITS had a reduced CL than those taught Biology using traditional method.

Table 3: Mean Score and Standard Deviation of CL Ratings of Male and Female Students Taught Biology with ITS.

Gender	N	Pre- BCLMS		Post- BCLMS		Mean Reduction
		$\bar{X}$	SD	$\bar{X}$	SD	
Male	35	7.40	2.23	5.46	2.11	1.94
Female	50	6.58	2.54	4.66	1.59	1.92
Mean Diff		0.82		0.08		0.02
Total	85					

Results in Table 3 show the mean CL rating of the male and female students. The result showed that male students had a mean score of 7.40 and 5.46 in the pre-BCLMS, and post- BCLMS with a corresponding 2.23 and 2.11 SD respectively. The female students had a mean score rating of 6.58 and 4.66 a corresponding SD of 2.54 and 1.59 respectively. The table further show the mean reduction for the two groups as 1.94 and 1.92 respectively. The mean difference between the two groups is 0.02 in favour of the female students.

Table4: ANCOVA Result of CL Ratings of Male and Female Students Taught Biology with BLIS

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	20.368[a]	2	10.184	3.132	.049	.071
Intercept	310.721	1	310.721	95.563	.000	.538
PRECLITS	7.286	1	7.286	2.241	.138	.027
GENDERITS	16.125	1	16.125	4.959	.029	.057
Error	266.620	82	3.251			
Total	2402.000	85				
Corrected Total	286.988	84				

Table 4 shows the ANCOVA result which indicates, that F(1, 82) = 4.959, the P-value = 0.029<0.05 level of significance. The result implies that there is a statistically significant difference in the mean CL rating of male and female students taught Biology with ITS in Makurdi Metropolis, the null hypothesis of no significant difference is rejected. This shows that female student had lower CL than their male counterparts when taught Biology using ITS.

Discussion of Findings

Findings from this study revealed that there is a significant difference between the mean CL rating of students taught Biology with ITS and those taught with Traditional method in favor of students taught Biology using ITS. This shows that the use of ITS to teach Biology has given the students more understanding about the concept taught because of the different learning platform ITS offers, students could use the different platform to access the teachers lesson, thus reducing the mental effort they would have used in processing the information that would have come from the teacher alone in the traditional method. The opportunity to relearn and learn at the student's pace through the various online platforms and resources offered by the IT classroom could have as well reduced CL and encouraged meaningful learning among biology students, as compared to those in the traditional method. This finding corroborates the findings of Mahadewi et al. (2018) that BLIS is effective in reducing students' CL, as students taught with BLIS had a lower CL than their counterparts taught using the Lecture method. Similarly, the finding aligns with Seedwell's (2019) that applying CLT in a technology rich classroom helps reduce the CL of accounting students. This study further supports the findings of Multu et al. (2022) that the use of BL in the classroom has helped reduce CL among vocational high school students. Students' CL was reduced in the experimental group, possibly because of the use of ITS, which helped to promote students' involvement in the lesson process, and they had the opportunity to watch and interact with the material themselves in the classroom during the period of the lesson and after. It also encourages peer tutoring. This finding is not consistent with that of Achor and Musa (2021) who reported that there is no significant difference between the mean CL of students exposed to the simulation strategy and those exposed to the demonstration method.

Furthermore, the study reveals a significant difference in the mean CL ratings between male and female students taught Biology using ITS in favor of male students taught Biology using ITS. This finding implies that male students had a reduced CL than their female counterparts exposed to Biology instruction with the use of ITS. This implies that the WM of the male students was not as loaded as that of the female students. The finding means that male students have a better understanding of the concepts taught. This difference in the male and female CL may be due to the learning differences and individual learning styles of the students. The results of this study are at variance with those of Akinbadewa (2015) and Oladele (2019), which indicate no difference in the cognitive mean rating between SS2 Biology male and female students. The ITS classroom was designed interactively, with a focus on the essential points that students need to learn to reduce their CL. Although the ITS is an interactive one and is not gender-biased, girls may be drawn to the technology used in the lessons, which could contribute to a reduction in their CL.

Conclusion

The study concluded that ITS had a great implication on the reduction of Biology students' CL. It was also concluded that female students had a reduced CL when exposed to the teaching of Biology with ITS.

Recommendations

It was therefore recommended that:

1. Biology teachers should adopt ITS, so as to regularly provide opportunities for students to interact, grasp and transform knowledge, and develop cognitive structures that can help in reducing CL.
2. Institutions that train teachers should introduce ITS as a teaching methodology that teachers in training are exposed to.
3. Science Teachers Association of Nigeria should advocate the use of ITS through conferences.
4. Regular training should be organised for Biology teachers on the use of ITS to reduce CL so that students understanding of biology concepts will be enhanced.

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