

Cognitive Load and Classroom Participation as Determinants of Students' Academic Achievement in Secondary School Mathematics in Lokja Education Zone, Kogi State

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Abstract

This study focused on cognitive load and classroom participation as determinants of students' academic achievement in secondary school Mathematics in Lokoja Education Zone, Kogi State. Three research questions and three corresponding null hypotheses guided the study. The correlational research design was adopted for the Study. The population of the study consisted of 1315 SSII students in 16 public secondary schools in Lokoja Education Zone Kogi State. Taro-Yamane Formula was used to obtain the sample size of 307 participants and the sample was drawn using multistage sampling procedure. Three instruments were used for data collections which were titled: Students' Cognitive Load Questionnaire (SCLQ), Classroom Participation Questionnaire (CPQ), and Mathematics Achievement Test (MAT). The instruments were subjected to face and content validation. The reliability coefficient values of 0.90, while 0.88 was obtained on CPQ using Cronbachs' Alpha Method. Also a reliability coefficient value of 0.80 was obtained for MAT using Kuder-Richardson20 Formula. The data collected were analyzed using Regression Analysis (correlation) to determine the relationships between the variables. The simple regression was used to answer research questions (1-2) while multiple regression was used to answer research question 3. However, Regression ANOVA was used to test all the null hypotheses at 0.05 level of significant. It was concluded that cognitive load significantly accounts for students' achievement in mathematics. It was also concluded that the degree to which students' active and passive participation that accounts for by their achievement in mathematics is not significant. Hence, the findings from the study revealed that the amount of variation in students' achievement in mathematics that is jointly accounted for by classroom participation and cognitive load is significant. It was recommended among other things that, Mathematics teachers should also take note of the instructional designs and teaching approaches which include breaking complex information into smaller chunks, using clear and explicit instructions, providing pre-training or examples and among others, in such a way that control and manage the cognitive loads of the students, so as to minimize the subpar achievement in Mathematics.

Key words: Mathematics, Achievement, Cognitive Load, Classroom Participation

Introduction

Mathematics plays a vital role in everyday life of so many people. Mathematics refers to the concept that studies about arithmetic, algebra, geometry and trigonometry (Ugwuanyi, Nwachukwu, Ugwuanyi. Okeke, Nworgu, Nwoye, Odo, Okeke, Inweregbuh, Osakwe, & Idoko, 2020). It is a discipline that appears to be abstract in nature, since it deals with human logical and abstract reasoning. It is a symbolic language that enables human beings to think, record, and

communicate ideas about the elements and relationships of quantity (Lerner & Johns, 2019). Mathematics is a fundamental science subject both in primary and secondary schools and no nation can develop without integrating Mathematics properly into the national life. This implies that Mathematics is the spring board for both technological and over all national development (Agwagah, Agasi & Obi, 2019). In formal education, Mathematics forms the basis of many of the

sciences such as physics, chemistry, biology, engineering, and information technology disciplines as well as the non-science disciplines such as accounting, economics, geography, and even physical education, music, and art (Ali & Jameel, 2016). Competency in Mathematics learning is vital to any individual and nation in domestic and business deals, scientific discoveries, technological breakthrough, problem-solving and decision making in different situations in life (Kele, 2018). The lack of proficiency in Mathematics among secondary school students in Nigeria has reached alarming proportions and is drawing the attention of Mathematics education researchers. Hence, due consideration must therefore be given to students' academic achievement in the subjects of Mathematics.

Achievement is seen as the result of the learning process; what students have gained as a result of the knowledge they have acquired. Academic achievement is a critical factor in students' future academic and professional careers since it is usually closely linked to successful university entrance or job success. Academically successful individuals are more likely to be accepted to more prestigious educational institutions, have better employment opportunities, earn a high income, and experience high life satisfaction (Liu, Peng & Luo, 2020). Academic achievement is the extent to which a student, teacher or institution has attained their short or long-term educational goals in terms of completion of educational benchmarks such as secondary school diplomas and bachelor's degrees. The students' academic achievement plays an important role in producing the best quality graduates who will become great leader and manpower for the country thus responsible for the country's economic and social development (Ali & Jameel, 2016). The quality of students' achievement remains a top priority for educators, which is meant for making a difference locally, regionally, nationally and globally. From these assertions, academic achievement in Mathematics can be considered as the level of learning outcome recorded by a student in Mathematics over a given period of learning. Further enquiry into the students' poor academic achievement in Mathematics, the researcher has decided to look into the combination of students' cognitive load and classroom participation as determinants of students' academic achievement.

Cognitive load is the total amount of mental activity imposed on the working memory in any one instant. Cognitive load tells us how much to tax a person's working memory since it is prone to

overloading while handling complex information. Ishani (2022) stated that cognitive load is, essentially a resource demand by the information & brain while it stays in our working memory. Sweller (2018) defined cognitive load as the amount of information that the working memory capacity can hold at one time. Sweller stressed that the capacity of human memory is limited, thus instructional processes should avoid overloading it with activities that do not genuinely advance learning. Working memory plays a pivotal role in a student's learning process. But, working memory has a limited capacity and it is vulnerable to overload, especially when we are learning complicated novel concepts. Cognitive load is therefore influenced by the number of elements that are interacting with each other in the working memory - the numerous bits of information that have to be processed simultaneously. There is only a certain amount of data that the person can hold onto. Due to its limitations in processing speed and endurance, working memory may significantly hinder human learning. According to Gupta and Zheng (2020), stated that cognitive load may have a significant impact on learners' capacity to solve complex problems in Mathematics. The authors stressed that the cognitive load that students have for Mathematics is very important to both the teaching and learning. It is commonly acknowledged that learners' achievement in complex learning, as Mathematics, might be influenced by the cognitive load during learning. According to Sweller (2018), there are three different types of cognitive load and they differ from each other depending on their relevance to learning namely: intrinsic, extraneous and germane cognitive load. Becton (2023) described intrinsic cognitive load as the difficulty of the learning task; that is the complexity of the task at hand. Intrinsic cognitive load is defined by the difficulty of the instructional materials that cannot be changed or altered. Again Fuhrman (2017) described intrinsic load as the inherent difficulty of the subject matter. Think of it as the RAM requirement for a piece of software, like a web-browser or a word processor. It is generally considered fixed; an instructional designer cannot change the intrinsic load. But while the difficulty of a subject cannot really be changed, certain practices such as sequencing and chunking can help reduce this load.

Extraneous load is a kind of load created due to the way the instructional materials are presented, which does not help in the learning process. Becton (2023) defined extraneous cognitive load the material and environment subjected to the students. Excessive

distractions lead to an increase in extraneous load. Sweller (2018) defined extraneous cognitive load as the mental load caused by improper instructional design like imposing redundant information in learning materials that require learners' additional processing effort. The extraneous cognitive load is irrelevant to learning and therefore should be eliminated. The extraneous load can be increased or reduced based on several factors – the type of task, whether or not the student has difficulties with attention, attentional demands for a task, etc. Fuhrman (2017) defined the extraneous load as the portion of memory that is taken up by processes not related to learning at all. Fuhrman stressed that instructional design strategies should aim to reduce extraneous load as much as possible by avoiding split attention and redundancy.

Germane Load includes the components that help the processing of information and contribute to the long-lasting construction of schemas. Becton (2023) defined germane cognitive load as the capacity of the working memory to link new ideas with information in the long-term memory. Sweller (2018) referred germane load as the mental load induced by the efforts to construct new knowledge or build new schema. A typical example of germane load is creating diagrams and flowcharts to perform complex tasks. The systematic organization of germane materials make complex learning easier and helps to remember. Hutberg (2017) defined germane load as that portion of the memory devoted to integrating new information, the creation and modification of schema. Therefore, germane load is where meta-cognitive strategies come into play. It is where students are aware of their thinking processes and able to adapt new information accordingly. Depending on its nature, cognitive load can either be helpful or detrimental in learning. Hence, for an effective learning process, one must: optimize extraneous cognitive load, manage intrinsic cognitive load; and promote germane cognitive load. Sweller stressed once more that information overload and workload overburdens are two factors that contribute to overload. As a result, cognitive overload causes stress, which makes students exhausted, angry, and unable to focus or participate in class activities, which results in forgetfulness and subpar achievement. Keeping in view all these points, researcher intends to conduct this study to examine how cognitive load (intrinsic, extraneous, and germane) can determine students' academic achievement in Mathematics. Hence, relevance in cognitive load instructional design encourages students

to participate in Mathematics lessons or activities and also boost their academic achievement in Mathematics.

Classroom participation is an extremely crucial element for learning and it is a proven fact that students learn and achieve better as well as retaining more when they are active participants. According to Hard and RaoShah, (2022), class participation is a multidimensional concept that comprises many aspects that suggest evidence of student engagement, such as preparation prior to class attendance, contribution to class activities and discussions. Ukoh, and Dibie (2020) defined classroom participation as a process whereby students speak in class, answer and ask questions, make comments and join in classroom discussions. Ukoh, and Dibie stressed that classroom participation has to do with the ability of students to actively engage in classroom activities which helps to facilitate learning and bring about improved academic achievement. Students can be active participants in class activities by answering questions voluntarily, demonstrating at the chalkboard, spontaneously offering their ideas and thoughts, communicating with peers or the teacher about tasks and completing written works. . Siti and Norliza (2016) stated that student's classroom participation can be viewed in two ways; active participation and passive participation, which are related to behavioral responses while in class. It is worthy of consideration when it comes to students' academic achievement in Mathematics that their activeness during teaching/learning may affect students' achievement either positively or negatively.

Active participation is the most recognizable form and is frequently graded by instructors or lecturers, in the secondary and university level, participation between teachers or lecturers and students is integral in the process of learning. Hirshfield and Koretsky (2018) defined active participation as students' participation in discussion activities, including questioning, expressing ideas, and giving opinions during the discussion session. Their questions or feedback seemed spontaneous and they looked happy when they were contributing their ideas and talking to the class. Students, who are actively involved in classroom participation, will reflect their higher satisfaction and attention level to the lesson. Therefore, active participation can be defined as a way of students engaging or contributing in the activities during classroom discussion either verbally or nonverbally. It is an educational approach that places the center of the process and requiring them to do meaningful learning activities.

Passive participation is seen students who were the least active in class were those who perceived classroom participation as being physically present in class. These students believed that being present showed that they were part of the class. Haroon (2019) revealed that passive participation is a situation where learners are rarely disruptive which is why they often go unnoticed and unchallenged. This lack of challenge results in poor progress. According to Siti and Norliza (2016), there are two types of passive students: positively passive and negatively passive. Positively passive students are those who chose to be quiet throughout the class because they felt that they learnt more by concentrating on what was going on in class. There was no need for them to spend time thinking about how to respond to their lecturer or classmates. This student believed that he would gain more knowledge by listening rather than participating. When the lecturer asked them a question, they attempted to answer. Negatively passive students are those who were very quiet because they were not concerned about their studies and were not interested in what goes on in class. These were the isolated few who were observed to be in their own world. They looked outside the window, had a glazed look on their face, stared at the book, and appeared to be disconnected from the rest of the class. Siti and Norliza (2016) revealed that the patterns of participation that emerged from the observation and interviews showed the basic patterns which ranged from active to passive participation. Therefore, passive participation is a traditional model of instruction wherein students play a less active role.

Research Questions

The following research questions were posed to guide the study:

1. what is the amount of variation in secondary school students' achievement in Mathematics that is attributed to cognitive load?
2. what is the amount of variation in secondary school students' achievement in Mathematics that is attributed to participation?
3. what is the amount of variation in secondary school students' achievement in Mathematics that is jointly attributed to cognitive load and classroom participation?

Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significant;

1. The amount of variation in secondary school students' achievement in Mathematics that is attributed to cognitive load is not significant.
2. The amount of variation in secondary school students' achievement in Mathematics that is attributed to participation is not significant.
3. The amount of variation in secondary school students' achievement in Mathematics that is jointly attributed to cognitive load and classroom participation is not significant.

Method

Research Design

A correlational survey research design was adopted for this study. A correlation survey design according to Nworgu (2015) is a scientific study in which a researcher investigates associations between variables.

Area of the Study

The study was conducted in Lokoja Education Zone, Kogi State. The education zone comprises two local government areas; Kogi and Lokoja local government areas.

Sample and Sampling Techniques

The sample size of the study comprised 307 SSII students. The sample size was obtained using Taro-Yamane formula. The sample was drawn using multistage sampling procedure. In the first stage, simple random sampling by balloting with replacement (by folded paper) was used to select two schools from Kogi LGA and six schools from Lokoja LGA. The simple random sampling by balloting with replacement (by folded paper) was used to ensure that each school has equal chance of being represented. That is eight schools were sampled from the two Local Government Areas in Lokoja Education Zones. In the second stage, simple random sampling with replacement (by folded paper) was also used to select two or more streams of SS11 in each of the sampled schools from the two local government areas depending on the number of streams in each sampled schools. This is to ensure that each stream has equal chance of being represented.

Instruments for Data Collection

Three instruments were used for the study. They are Mathematics Achievement Test (MAT), Students' Cognitive Load Questionnaire (SCLQ), and Classroom Participation Questionnaire (CPQ). The instruments, Students' Cognitive Load Questionnaire

(SCLQ), and Classroom Participation Questionnaire (CPQ) were adapted while Mathematics Achievement Test (MAT) was developed by the researcher.

The Mathematics Achievement Test (MAT) has two sections (A & B). Section A contains the instructions like 2 hours' time allocated and demographic data of the student like student identification number while section B consists of forty (40) multiple choice items which were developed by the researcher based on SS2 mathematics contents. Each item of the MAT has four response options, lettered A – D, the test items covered all the modified cognitive levels which include remembering (6%), understanding (22%), applying (20%), analyzing (18%), evaluating (14%) and creating (20%) in line with Blooms' taxonomy of educational objectives which covered the following SS11 topics based on the interest of the researcher; Binary (16%), Matrix (20%), Trigonometry (18%), Probability (20%), Algebraic expression (12%), and Quadratic equation (22%). The marking guide for MAT was developed in line with the questions and each correct answer was allotted 1 mark while a wrong answer attracted zero, making a total of 40 marks.

The Students' Cognitive Load Questionnaire (SCLQ) was adapted and modified by the researcher for the current study. The original instrument on SCLQ was gotten from the internet (google .com) which was viewed on Frontiers. The items were structured based on the cognitive load they are measuring. The researcher modified them by adding Mathematics in the statement to meet the need of the current study. The modified SCLQ has two sections (A & B). Section A contains the instructions and demographic data of the student while section B contains thirty (30) items statement. The instruments employed a 4-point Likert scale with response options: Strongly Agree (SA), Agree (A), Disagree (D) and Strongly Disagree (SD) with points 4, 3, 2, 1 respectively.

Classroom Participation Questionnaire (CPQ) was adapted and modified by the researcher for the current study. The original instrument on CPQ was gotten from the internet (google .com) which was viewed on Pinterest. The items were structured based on the classroom participation rubric. The researcher modified them by adding Mathematics activities to meet the need of the current study. The modified CPQ

has two sections (A & B). Section A contains the instructions and demographic data of the student while section B contains twenty-six (26) items statement. The instrument employed a 4-point Likert scale with response options: Strongly Agree (SA), Agree (A), Disagree (D) and Strongly Disagree (SD) with points 4, 3, 2, 1 respectively.

Validation of the Instruments

The three instruments were subjected to face and content validation. SCLQ and CPQ were subjected to face validation while only MAT was subjected to content validation. The MAT, SCLQ and CPQ items, the purpose of the study, hypotheses and research questions were subjected to face validation by three experts, two from Mathematics unit, and one from Measurement and Evaluation unit, both from Department of Science Education of the University of Nigeria, Nsukka. The experts were specifically requested to scrutinize the instruments in line with the purpose of the study, research questions and hypotheses. To determine the content validation of MAT, a table of specification was prepared based on the modified Blooms' taxonomy.

Reliability of the Instruments

The instruments - Students' Cognitive Load Questionnaire (SCLQ), Classroom Participation Questionnaire (CPQ) and Mathematics Achievement Test (MAT) were trial tested on 30 SS11 students in Ankpa education zone of Kogi state which was not part of the sampled education zone for the study. The responses obtained from the students on SCLQ and CPQ were subjected to Cronbachs' Alpha method to ascertain the internal consistency of the instruments which gave co-efficient values of 0.90 and 0.80 respectively. The MAT was subjected to Kuder-Richardson 20 (K-R₂₀) formula. This gave a reliability co-efficient value of 0.80.

Method of Data Analysis

The data collected from the sampled schools were analyzed using Regression Analysis (correlation) to determine the relationships between the variables. The simple regression was used to answer research questions (1 and 2) while multiple regressions was used to answer research questions 3. However, Regression ANOVA was used to test all the null hypotheses at 0.05 level of significant.

Results

Table 1: ANOVA Regression analysis of variation in secondary school students' mathematics achievement that is attributed to all the cognitive loads

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	255.374	3	85.125	2.468	.062
Residual	10449.284	303	34.486		
Total	10704.658	306			

a. Dependent Variable: MAT

b. Predictors: (Constant), CL

Table 1 reveals that amount of variation in students' achievement in mathematics that is jointly accounted for by cognitive loads is not significant, $F(3, 306) = 2.468$, $p = .062$. Therefore, the null hypothesis was failed to reject since the p-value of .062 is greater than the .05 level of significance. Thus, the inference

drawn is that cognitive loads may not determine students' achievement in mathematics. The researcher therefore, concludes that there is no significant relationship on the amount of variation in students' achievement in Mathematics that is accounted for cognitive loads.

Table 2: ANOVA Regression analysis of variation in secondary school students' mathematics achievement that is attributed to all the aspect classroom participation

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	10.480	2	5.240	.149	.862
Residual	10694.178	304	35.178		
Total	10704.658	306			

a. Dependent Variable: MAT

b. Predictors: (Constant), CP

Table 2 reveals that amount of variation in students' achievement in mathematics that is accounted for by classroom participation is not significant, $F(2, 306) = 0.149$, $p = .862$. Therefore, the null hypothesis was failed to reject since the p-value of .862 is greater

than the .05 level of significance. The researcher therefore, concludes that there is no significant relationship on the amount of variation in students' achievement in Mathematics that is accounted for classroom participation.

Table 3: ANOVA Regression analysis of variation in secondary school students' mathematics achievement that is attributed to cognitive load and classroom participation

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	276.251	2	138.126	4.027	.019
Residual	10428.406	304	34.304		
Total	10704.658	306			

b. Predictors: (Constant), CL, CP

Result in Table 3 reveals that amount of variation in students' achievement in mathematics that is jointly accounted for by classroom participation is significant, $F(2, 306) = 4.027, p = .019$. Therefore, the null hypothesis is rejected since the p-value of .019 is less than the .05 level of significance. Thus, the inference drawn is that cognitive load and classroom participation positively determines students' achievement in mathematics.

Discussion: The finding in Table 1 revealed that the amount of variation in students' achievement in mathematics that is jointly attributed for cognitive load is not significant. Table 2 reveals that amount of variation in students' achievement in mathematics that is accounted for by classroom participation is not significant. Result in Table 3 reveals that amount of variation in students' achievement in mathematics that is jointly accounted for by classroom participation is significant

Conclusion: Based on the findings of the study, it was concluded that the amount of variation in students' achievement in Mathematics that is jointly accounted for by cognitive load and classroom participation is significant. This implies that the joint combination of cognitive load and classroom participation towards teaching and learning enable students to improve and achieve high in their academic especially in Mathematics.

Recommendations: Based on the findings of the study, the following recommendations were made:

1. Mathematics teachers should take note of the instructional design and teaching approaches which include breaking complex information into smaller chunks, using clear and explicit instructions, providing pre-training or examples and among others, in such a way that control and manage the cognitive loads of the students, so as to minimize the subpar achievement in Mathematics.
2. Mathematics teachers should consistently checkmate the classroom participation of the students by consistently giving them class works and assignments that are challenging and thought-engaging.

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