



EFFECT OF COGNITIVE LOAD MANAGEMENT & ITS DIMENSIONS ON SECONDARY SCHOOL STUDENTS' ATTITUDE TOWARDS CHEMISTRY

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ABSTRACT

Chemistry learning requires students to process abstract concepts, symbolic representations, mathematical relationships, laboratory procedures and interconnected ideas. This may impose substantial demands on working memory, at times leading to cognitive overload. This study examined the predictive relationship between cognitive load management and secondary school students' attitude towards Chemistry in Anambra State, Nigeria, with a focus on the relative contributions of intrinsic load management, extraneous load reduction and germane load enhancement. The study adopted a predictive correlational research design. The population comprised 20,418 Senior Secondary Two (SS2) students offering Chemistry in public secondary schools in Anambra State. A sample of 1,021 students was selected through a multistage sampling procedure. Data were collected using the 30-item Students' Cognitive Load Management Questionnaire (SCLMQ) and the 20-item Chemistry Attitude Scale (CAS), with Cronbach alpha coefficients of .91 and .87, respectively. Simple and multiple linear regression analyses were employed at the .05 level of significance. Composite cognitive load management did not significantly predict students' attitude towards Chemistry, $R = .003$, $R^2 = .000$, $F(1, 1019) = .009$, $p = .925$. However, the three dimensions jointly produced a statistically significant regression model, $R^2 = .009$, $F(3, 1017) = 2.957$, $p = .032$. Intrinsic load management made a significant negative contribution ($\beta = -.092$, $p = .010$), while extraneous load reduction made a significant positive contribution ($\beta = .088$, $p = .015$). Germane load enhancement did not make a significant contribution ($\beta = -.007$, $p = .830$). The findings suggest that cognitive load management should not be treated as a homogeneous construct when examining students' attitudes towards Chemistry. Chemistry instruction should particularly minimise unnecessary cognitive demands while appropriately sequencing complex content and supporting meaningful cognitive processing.

Keywords: cognitive load management; intrinsic load; extraneous load; germane load; attitude towards Chemistry; secondary school students.

Introduction

Chemistry occupies an important position in science education because of its relevance to health, agriculture, energy, environmental management and industrial development. At the secondary school level, however, students often encounter difficulties in understanding and applying Chemistry concepts. Abumchukwu and Obikezie (2021) identified persistent difficulties areas to include stoichiometric calculations, balancing chemical equations, qualitative analysis, volumetric analysis and organic Chemistry. These areas require learners to coordinate scientific symbols, formulae, calculations, laboratory procedures and several interacting concepts simultaneously. Such demands may place considerable pressure on the limited capacity of working memory. Consequently, students may experience difficulty when



instructional materials present unnecessary information; when explanations are poorly organised, or when new concepts are introduced without adequate consideration of prerequisite knowledge. These might lead to cognitive overload. Students' difficulties in Chemistry are not exclusively cognitive. Their attitude towards the subject is also an important dimension of Chemistry learning, (Achor and Agogo, 2021). Attitude encompasses students' feelings, dispositions and evaluative responses towards Chemistry and may be reflected in their interest, perceived difficulty, perceived value and motivation to learn the subject.

One theoretical perspective capable of explaining the cognitive demands associated with Chemistry learning is Cognitive Load Theory (CLT). Sweller (1988) proposed that learning is constrained by the limited capacity of working memory and that learning materials differ in the extent to which their elements must be processed simultaneously. Within this framework, intrinsic load relates to the inherent complexity of learning material, extraneous load concerns unnecessary cognitive demands arising from the manner in which information is presented, while germane processing refers to cognitive activity directed towards constructing and automating useful knowledge structures. Against this theoretical background, cognitive load management provides a practical framework for translating the principles of Cognitive Load Theory into specific strategies students can employ to facilitate effective Chemistry learning.

Cognitive load management refers to the regulation of mental demands associated with learning. In the present study, it is conceptualised through three dimensions: intrinsic load management, extraneous load reduction and germane load enhancement. Intrinsic load management concerns students' ability to handle the inherent complexity of Chemistry learning tasks. Extraneous load reduction concerns minimising unnecessary mental processing arising from distractions, unclear explanations or poorly organised learning materials. Germane load enhancement involves productive cognitive activities that facilitate meaningful learning, such as self-explanation, rehearsal and mental organisation of knowledge. The relevance of these dimensions to students' attitude towards Chemistry is supported by the possibility that the cognitive experiences students encounter during learning may influence how they perceive the subject. When Chemistry tasks are perceived as manageable and learning materials are clearly structured, students may be more willing to engage with the subject. Conversely, persistent experiences of excessive or unnecessary cognitive demands may contribute to negative perceptions of Chemistry.

Empirical evidence, however, does not provide a uniform picture. Adeyemi and Bello (2021), reported a positive relationship between cognitive load management strategies and students' attitudes towards Chemistry in Oyo State. The present investigation differs in location, sample and analytical emphasis and examines the three dimensions separately. The need to examine the dimensions separately is important because combining different forms of cognitive load management into one composite score may obscure relationships that emerge when individual dimensions are examined. The present study therefore examined both the predictive value of composite cognitive load management and the relative contributions of intrinsic load management, extraneous load reduction and germane load enhancement to students' attitude towards Chemistry.

Research Questions

The following research questions guided the study:

1. What is the predictive value of cognitive load management on secondary school students' attitude towards Chemistry in Anambra State?



2. What are the relative contributions of intrinsic load management, extraneous load reduction and germane load enhancement to the prediction of secondary school students' attitude towards Chemistry?

Hypotheses

The null hypotheses were tested at the 0.05 level of significance

1. Cognitive load management does not significantly predict secondary school students' attitude towards Chemistry in Anambra State.
2. The relative contributions of intrinsic load management, extraneous load reduction and germane load enhancement to the prediction of secondary school students' attitude towards Chemistry are not statistically significant.

Method

Research Design

The study adopted a predictive correlational research design. The design was appropriate because the study sought to determine the extent to which cognitive load management and its dimensions predicted students' attitude towards Chemistry without manipulating the variables.

Population and Sample

The population comprised 20,418 Senior Secondary Two (SS2) students offering Chemistry in public secondary schools in Anambra State. The state has six education zones: Aguata, Awka, Nnewi, Ogidi, Onitsha and Otuocha. Through simple random sampling, Awka, Nnewi and Onitsha education zones were selected. Bowley's proportionate allocation procedure was subsequently used to distribute the sample among the selected zones. The final sample consisted of 1,021 SS2 Chemistry students.

Instruments

Two instruments were used for data collection: the Students' Cognitive Load Management Questionnaire (SCLMQ) and the Chemistry Attitude Scale (CAS). The SCLMQ comprised 30 items organised into intrinsic load management, extraneous load reduction and germane load enhancement, with 10 items per dimension. The CAS comprised 20 items designed to measure students' attitude towards Chemistry, including interest and enjoyment, perceived difficulty, value and relevance, and motivation to learn Chemistry.

Validity and Reliability

Experts validated the instruments. We determined reliability using Cronbach's alpha. The SCLMQ obtained an overall reliability coefficient of .91, while the CAS obtained .87, indicating satisfactory internal consistency.

Data Collection and Analysis

The instruments were administered to sampled students in their schools with the assistance of research assistants and Chemistry teachers. Simple linear regression was used to determine the predictive value of composite cognitive load management, while multiple linear regression was used to determine the relative contributions of the three dimensions. The coefficient of determination (R^2) was used to quantify explained variance, and standardised beta coefficients (β) were used to compare relative contributions. Statistical decisions were made at $\alpha = .05$.



Results

Presentation of Results

Research Question 1: What is the predictive value of cognitive load management on secondary school students' attitude towards Chemistry in Anambra State?

Table 1: Simple Linear Regression Analysis of the Prediction of Cognitive Load Management on Students' Attitude towards Chemistry

Model	R	R ²	Adjusted R ²	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.003 ^a	.000	-.001	8.494	.000	.009	1	1019	.925

a. Predictors: (Constant), CLM

Table 1 reveals the prediction of students' attitude towards Chemistry by their cognitive load management. The Pearson correlation coefficient ($R = .003$) indicates a low positive predictive relationship between cognitive load management and students' attitude towards Chemistry. The coefficient of determination ($R^2 = .000$) implies that cognitive load management does not predict any change in students' attitude towards Chemistry in Anambra State.

Null Hypothesis 1: Cognitive load management is not a significant predictor of secondary school students' attitude towards Chemistry in Anambra State.

Table 2: ANOVA Analysis of the Prediction of Cognitive Load Management on Students' Attitude towards Chemistry

Model		Sum of Squares	Df	Mean Square	F	Sig.	Decision
1	Regression	.643	1	.643	.009	.925 ^b	Not Sig.
	Residual	73526.477	1019	72.156			
	Total	73527.120	1020				

a. Dependent Variable: Attitude

b. Predictors: (Constant), CLM

The result of the ANOVA analysis from Table 2 shows a non-statistically significant prediction of cognitive load management on students' attitude towards Chemistry, $F(1, 1019) = .009$, $p > 0.05$. Since the p-value (.925) is greater than the 0.05 level of significance, the null hypothesis was not rejected. This decision indicates that cognitive load management is not a significant predictor of students' attitude towards Chemistry in Anambra State.

Research Question 2: What are the relative contributions of the dimensions of cognitive load management (intrinsic, extraneous and germane) to prediction of secondary school students' attitude towards Chemistry in Anambra State?



Table 3: Multiple Regression Analysis on the Relative Contributions of the Dimensions of Cognitive Load Management (Intrinsic, Extraneous and Germane) to Students' Attitude towards Chemistry

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Decision
	B	Std. Error	Beta			
(Constant)	49.340	2.068		23.864	.000	
1 Intrinsic load management	-.162	.063	-.092	-2.576	.010	Sig.
Extraneous load reduction	.150	.062	.088	2.441	.015	Sig.
Germane load enhancement	-.012	.057	-.007	-.215	.830	Not sig.
df	(3,1017)					
F	2.957					
R ²	.009					
P-value	.032					Sig.

The multiple regression analysis, as presented in Table 3, shows the relative contributions of the dimensions of cognitive load management to students' attitude towards Chemistry. The results show that the intrinsic load management (-.162) and germane load enhancement (-.012) dimensions of cognitive load management were negatively associated with students' attitude towards Chemistry. On the other hand, the extraneous load reduction (.150) was positively associated with the attitude of students in Chemistry.

Null Hypothesis 2: The relative contributions of the dimensions of cognitive load management (intrinsic, extrinsic and germane) to the prediction of secondary school students' attitude towards Chemistry in Anambra State are not significant.

The result of the multiple regression analysis presented in Table 3 shows that the individual contributions of the intrinsic load management $p(.010)$ and extrinsic load reduction $p(.015)$ dimensions of cognitive load management to students' attitude towards Chemistry were statistically significant, since their respective p -values were less than the .05 alpha level. On the other hand, the contribution of the germane load enhancement $p(.830)$ dimension to students' attitude towards Chemistry was not statistically significant, since its p -value was greater than the .05 alpha level. The overall $p(.032)$, which is less than the 0.05 alpha level, indicates that the relative contributions of the intrinsic, extraneous and germane dimensions of cognitive load management on students' attitude towards Chemistry in Anambra State is significant. Thus, the null hypothesis was rejected.

The estimated regression equation was: $\text{Attitude} = 49.340 - 0.162(\text{ILM}) + 0.150(\text{ELR}) - 0.012(\text{GLE})$. The second null hypothesis was rejected for the overall dimensional model; at the individual predictor level, intrinsic load management and extraneous load reduction were significant, whereas germane load enhancement was not.

Discussion of Findings

The study found that composite cognitive load management did not significantly predict secondary school students' attitude towards Chemistry. The relationship was virtually zero ($R = .003$), and the regression model explained no meaningful proportion of variance in attitude ($R^2 = .000$). This suggests that a high overall score on cognitive load management cannot, by itself, be interpreted as evidence of a more favourable attitude towards Chemistry. This finding



differs from the positive association reported by Adeyemi and Bello (2021) among secondary school students in Oyo State. The difference may be associated with contextual and methodological variations between the studies. The present investigation was conducted in Anambra State and involved a larger sample, while cognitive load management was examined as a multidimensional construct.

The dimensional analysis produced a different result. The three dimensions jointly predicted students' attitude towards Chemistry significantly, although they accounted for only 0.9% of the variance. This small effect indicates that cognitive load management is only one of many factors associated with students' attitudes towards Chemistry. Intrinsic load management (ILM) made a statistically significant negative contribution ($\beta = -.092$). This should not be interpreted to mean that managing the complexity of Chemistry learning is inherently harmful. Rather, after the other dimensions were statistically controlled, students reporting greater intrinsic-load-management behaviours tended to have slightly lower attitude scores. One possible explanation is that students who frequently employ strategies for dealing with difficult Chemistry content may themselves be experiencing greater difficulty with the subject. Because the present study employed a predictive correlational design, causal conclusions cannot be drawn.

Extraneous load reduction (ELR) made a statistically significant positive contribution to students' attitude ($\beta = .088$, $p = .015$). This finding highlights the potential importance of reducing unnecessary cognitive demands during Chemistry instruction. Clear explanations, logically organised materials, concise instructions and appropriately designed representations may help students concentrate on the essential features of Chemistry concepts rather than expend mental effort on irrelevant information. Germane load enhancement (GLE) did not make a statistically significant contribution ($\beta = -.007$, $p = .830$). This result suggests that the self-reported productive cognitive processing measured by the study did not independently explain meaningful differences in students' attitudes after intrinsic and extraneous load dimensions were controlled.

Taken together, the findings demonstrate the importance of distinguishing among the dimensions of cognitive load management. Although the composite measure was not a significant predictor, the dimensional model was statistically significant, with intrinsic load management and extraneous load reduction emerging as significant predictors.

Conclusion

Composite cognitive load management did not significantly predict secondary school students' attitude towards Chemistry in Anambra State. However, the three dimensions jointly produced a statistically significant prediction of attitude, although their combined explanatory power was small. Intrinsic load management made a significant negative contribution, extraneous load reduction made a significant positive contribution, while germane load enhancement did not make a significant contribution. Cognitive load management should therefore not be regarded as a homogeneous construct in explaining students' attitudes towards Chemistry.

Recommendations

1. Chemistry teachers should deliberately reduce extraneous cognitive demands through clear explanations, concise instructions, well-organised learning materials and appropriately designed diagrams.
2. Chemistry content involving high levels of element interactivity should be sequenced from relatively simple to more complex concepts, with adequate attention to students' prerequisite knowledge.



3. Teachers should provide scaffolding, worked examples and opportunities for clarification before requiring students to independently solve highly complex Chemistry problems.
4. Chemistry textbook authors should apply cognitive-load principles through logical sequencing, clear headings, uncluttered presentation and appropriately integrated diagrams and worked examples.
5. Teacher education and professional-development programmes should expose Chemistry teachers to practical approaches for identifying and reducing extraneous cognitive demands.
6. Future researchers should employ experimental and longitudinal designs to determine whether deliberate cognitive-load-management interventions can produce changes in students' attitudes towards Chemistry.

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