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OPTIMIZING THE VIRTUAL LEARNING ENVIRONMENT THROUGH PROMPTING STRATEGIES TO REDUCE STUDENTS' COGNITIVE LOAD IN BIOGRAPHY TEXT LEARNING

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Abstract

The rapid adoption of Virtual Learning Environments (VLE) in literacy instruction presents both opportunities and challenges, particularly concerning the cognitive load imposed on students when comprehending complex narrative texts such as biographies. This study investigates the effectiveness of both process-oriented and content-oriented prompting strategies within a VLE in reducing students' cognitive load during biographical text instruction. Drawing upon Cognitive Load Theory (CLT) and Mayer's seven principles of multimedia learning, this study employed a quasi-experimental design involving 65 secondary school students, who were randomly assigned to either an experimental group (utilizing a VLE with reinforced prompting) or a control group (utilizing a conventional VLE). The findings reveal that students in the prompting-enhanced VLE class demonstrated significantly lower extrinsic cognitive load and higher germane cognitive load compared to the control group. Process-oriented prompts effectively mitigated extraneous cognitive processing, whereas content-related prompts enhanced learner motivation and facilitated deeper engagement with the biographical texts. These results affirm that well-designed prompts within a VLE play a pivotal role in literacy instruction, offering practical pedagogical implications for educators seeking to balance the affordances of technology with students' cognitive constraints.

Keywords: *Virtual Learning Environment (VLE), prompting strategies, cognitive load, biographical texts, instructional design, Cognitive Load Theory (CLT).*

Abstrak

Adopsi *Virtual Learning Environment* (VLE) yang pesat dalam pembelajaran literasi membawa peluang sekaligus tantangan, terutama terkait beban kognitif siswa saat memahami teks naratif kompleks seperti biografi. Penelitian ini menyelidiki efektivitas strategi *prompting* baik yang berorientasi pada proses maupun konten dalam VLE untuk mengurangi beban kognitif siswa pada pembelajaran teks biografi. Dengan menggunakan Teori Beban Kognitif (*Cognitive Load Theory*/CLT) dan tujuan prinsip Pembelajaran Multimedia dari Mayer, penelitian ini menerapkan desain kuasi-eksperimental dengan 65 siswa sekolah menengah yang dibagi secara acak ke dalam kelompok eksperimen, yaitu; VLE dengan penguatan *prompting* sebagai kelompok eksperimen dan VLE konvensional sebagai kelompok kontrol. Temuan menunjukkan bahwa siswa pada kelas VLE berbantuan *prompting* memiliki beban kognitif ekstrinsik lebih rendah dan beban kognitif *germane* yang lebih tinggi dibandingkan kelompok kontrol. *Prompt* proses secara efektif mengurangi pemrosesan kognitif yang tidak perlu, sementara *prompt* terkait konten meningkatkan motivasi dan keterlibatan

yang lebih dalam dengan teks biografi. Hasil ini menegaskan bahwa *prompt* yang dirancang dengan baik dalam VLE berperan penting untuk pembelajaran literasi, karena menawarkan implikasi praktis bagi pendidik dalam menyeimbangkan potensi teknologi dengan keterbatasan kognitif siswa.
Kata kunci: *Virtual Learning Environment (VLE)*, strategi *prompting*, beban kognitif, teks biografi, desain instruksional, Teori Beban Kognitif.

INTRODUCTION

The transformation of Virtual Learning Environments (VLE) in education has fundamentally reshaped the landscape of literacy instruction, offering learners interactive and personalized learning experiences (Junker et al., 2025). Although VLEs are replete with multimedia content and interactive features, they can concomitantly impose a substantial extraneous cognitive load that tends to impede learners' cognitive processes (Sweller, 2023; Poupard et al., 2024). Wang (2025) identified this empirical reality as a serious cognitive challenge for learners, particularly when interface design and material presentation fail to account for their limited working memory capacity and academic retention. This paradox is acutely felt in the teaching of complex narrative texts such as biographies, which require learners to simultaneously process factual information, chronological sequences, and interpretive meanings.

The instruction of biographical texts as a literary genre possesses unique and complex characteristics that demand deep cognitive processing, ranging from text structure comprehension and character analysis to the interpretation of life values. Readers must navigate extensive factual details, comprehend causal relationships among life events, and construct a coherent mental representation of an individual's life trajectory. Within the VLE context, these demands are exacerbated by the need to manage diverse information sources, navigate hypertextually connected content, and filter relevant from irrelevant information (Chen et al, 2024). Without appropriate scaffolding, students are susceptible to cognitive overload, which ultimately undermines their comprehension and learning outcomes.

Prompting strategies have been devised as a promising pedagogical intervention to mitigate cognitive load in digital learning environments. Specifically, prompts can orient learners' cognitive resources toward essential information processing while simultaneously reducing their extraneous cognitive demands (Han *et al.* 2025; Li et al., 2025; Breitwieser, *et al.* 2026). Recent research indicates that well-designed prompts can enhance learning performance, reduce cognitive load, and foster intrinsic motivation across various online learning contexts (Zeitlhofer et al. 2023; Kirschner et al., 2016).

Despite these encouraging findings, significant theoretical and empirical gaps persist regarding prompting strategies within VLEs specifically tailored to biographical text instruction. Although Cognitive Load Theory (Sweller, 2022; Sweller et al., 2022) and the Cognitive Theory of Multimedia Learning (Mayer, 2024) have provided robust foundations for instructional design, their specific application to biographical narrative texts remains rarely operationalized into prompting strategies. Most research continues to treat prompting as a unitary construct, without systematically distinguishing between the cognitive functions of the two distinct prompt types within a VLE environment (Triana-Vera & López-Vargas, 2025; Han *et al.* 2025). In fact, these two types of prompts are theoretically posited to operate through

different mechanisms: process-oriented prompts tend more toward reducing extraneous load, whereas content-oriented prompts hold greater potential for enhancing germane load (Sweller & Roussel, 2022). To date, no theoretical model has explicitly integrated both types of prompts simultaneously within a single VLE framework for Indonesian language instruction, particularly concerning biographical texts.

Concurrently, empirical research that specifically examines the differential effects of both prompt types on the three dimensions of cognitive load (intrinsic, extraneous, and germane) within the context of biographical text learning remains exceedingly scarce. In their systematic reviews, Wang et al. (2024) and Poupard et al. (2024) highlight that VLE and cognitive load research tends to be concentrated in specific domains, such as science, technology, engineering, and mathematics (STEM). Meanwhile, the literacy domain, including meaning-laden historical and biographical texts, remains insufficiently addressed. Existing studies have largely focused on the effects of prompting on general cognitive learning outcomes (Smith et al., 2024; Sandoval et al. 2024), without specifically measuring its contribution to reducing extraneous load and enhancing germane load as mediating variables. In the Indonesian context, although Nugroho & Hartono (2023) have examined cognitive load reduction in biographical texts through a multimodal approach, their research did not specifically explore the role of VLE-integrated prompting strategies as a primary intervention variable.

Addressing these theoretical and empirical lacunae, the present study offers a novel model for integrating prompting strategies that explicitly examines the differential effects of both prompt types within a VLE for biographical texts. This model operationalizes the postulates of Sweller (2023) and Mayer (2024) by adapting them to the unique characteristics of historical narrative texts, thereby enriching the broader corpus of Cognitive Load Theory beyond the STEM domain. Empirically, this study seeks to simultaneously test all three dimensions of cognitive load and provide novel empirical evidence regarding the causal mechanisms through which prompting operates to mitigate information overload in VLEs. This research is expected to make a significant contribution to the development of more humanistic and cognitively friendly VLE instructional designs.

METHOD

Research design and methodological approach

This study employs a quasi-experimental research design with a nonequivalent control group design (Creswell, 2009). The primary aim is to examine the causal effect of the independent variable on the dependent variable (Kerlinger, 2000). The independent variable consists of two distinct conditions: (1) a Virtual Learning Environment (VLE) model reinforced with prompting strategies (experimental group), and (2) a conventional VLE model without systematic prompting (control group). The dependent variable is students' cognitive load, measured across its three dimensions (intrinsic, extraneous, and germane load) as conceptualized within Cognitive Load Theory (Sweller, 2023; Leppink et al., 2013).

Both groups undergo pretest and posttest measurements to capture changes in cognitive load following the intervention. The collected quantitative data are analyzed using descriptive statistics and inferential analyses, such as independent samples t-tests or ANCOVA, to

compare the cognitive load levels between the two groups and to determine the significance of the observed differences. This design allows for a rigorous assessment of whether the integration of prompting strategies in the VLE significantly reduces students' cognitive load in biography text learning compared to conventional VLE settings.

Participants

A total of 65 senior high school students, enrolled in Grade X in the natural science track (IPA) at SMA Darul Ulum, Bojonegoro, Indonesia, served as the research participants. Participants were assigned to the experimental group (n = 32), which received the prompting-enhanced VLE intervention, and the control group (n = 33), which engaged with the conventional VLE without systematic prompts. The sample consisted of 34 female (52.3%) and 31 male (47.7%) students, with ages ranging from 15 to 17 years (M = 15.8, SD = 0.7). All participants had prior experience with VLEs through their school's learning management system and were randomly assigned to the two conditions to minimize selection bias. The demographic distribution across groups is presented in Table 1.

Table 1. Demographic Profile of Participants

Characteristic	Experimental Group (n = 32)	Control Group (n = 33)	Total (N = 65)
Gender			
Male	15 (46.9%)	16 (48.5%)	31 (47.7%)
Female	17 (53.1%)	17 (51.5%)	34 (52.3%)
Age (Years)			
Range	15 – 17	15 – 17	15 – 17
Mean (SD)	15.8 (0.7)	15.7 (0.6)	15.8 (0.7)
Class	XA	XB	X A&B
Prior VLE Experience	Yes (100%)	Yes (100%)	Yes (100%)

As shown in Table 1, both groups were relatively balanced in terms of gender distribution and age, ensuring that the two conditions were comparable prior to the intervention. This equivalence supports the internal validity of the quasi-experimental design (Creswell, 2009), allowing any post-intervention differences in cognitive load to be attributed more confidently to the prompting strategies rather than to pre-existing demographic disparities.

Procedure

The study was conducted over four weeks. In Week 1, all participants completed a pretest of biography text comprehension and a baseline cognitive load measure. Weeks 2-3 constituted the intervention phase, during which participants in both groups engaged with the biography texts through their respective VLE conditions over four sessions (two texts per week, 45 minutes per session). The experimental group received prompting strategies embedded within the VLE, while the control group accessed the same content without prompts. In Week 4, participants completed the posttest comprehension assessment and the cognitive load

questionnaire.

Data Analysis

Data were analyzed using descriptive statistics, independent samples t-tests to compare groups on cognitive load dimensions and comprehension scores, and multiple regression analysis to examine the relationship between cognitive load and comprehension performance. All analyses were conducted using SPSS version 26, with statistical significance set at $p < .05$.

RESULT AND DISCUSSION

RESULTS

Descriptive Statistics

Descriptive statistics for cognitive load dimensions and comprehension scores across both experimental and control groups are presented in Table 2. The experimental group (n = 32) demonstrated lower mean scores on extraneous cognitive load and higher mean scores on germane cognitive load compared to the control group (n = 33), while intrinsic load remained relatively comparable across both conditions. These preliminary findings suggest that the prompting-enhanced VLE may have contributed to more favorable cognitive load profiles and better comprehension performance.

Table 2. Descriptive Statistics of Cognitive Load and Comprehension Scores

Descriptive Statistics

No.	Variable	Experimental Group (n = 32)	Control Group (n = 33)	Total (N = 65)
1	**Intrinsic Load**			
	Mean (M)	4.09	4.12	4.11
	Standard Deviation (SD)	1.21	1.28	1.24
2	**Extraneous Load**			
	Mean (M)	2.91	4.38	3.65
	Standard Deviation (SD)	1.15	1.39	1.42
3	**Germane Load**			
	Mean (M)	5.41	4.18	4.78
	Standard Deviation (SD)	1.02	1.20	1.25
4	**Comprehension Score**			
	Mean (M)	16.7	13.4	15.0
	Standard Deviation (SD)	2.3	3.0	2.9

As shown in Table 2, the experimental group reported a substantially lower mean extraneous load (M = 2.91, SD = 1.15) compared to the control group (M = 4.38, SD = 1.39). Conversely, the experimental group demonstrated a higher mean germane load (M = 5.41, SD = 1.02) than the control group (M = 4.18, SD = 1.20). Comprehension scores also favored the experimental group (M = 16.7, SD = 2.3) over the control group (M = 13.4, SD = 3.0). Intrinsic

load means were nearly identical across groups (experimental: M = 4.09, SD = 1.21; control: M = 4.12, SD = 1.28), confirming the comparability of text complexity in both conditions.

Differences in Cognitive Load

To determine whether the observed differences in cognitive load between the two groups were statistically significant, independent samples t-tests were conducted for each cognitive load dimension. Table 3 summarizes the results of these analyses.

Table 3. Independent Samples t-Test Results for Cognitive Load Dimensions

Variable	t-value	df	p-value	Mean Difference	Effect Size (Cohen's d)
Intrinsic Load	0.10	63	0.921	0.03	0.02
Extraneous Load	-4.72	63	< 0.001*	-1.47	1.18
Germane Load	4.44	63	< 0.001*	1.23	1.10

The analysis revealed a statistically significant difference in extraneous cognitive load between the experimental and control groups, $t(63) = -4.72$, $p < 0.001$, with a large effect size ($d = 1.18$). This indicates that students in the prompting-enhanced VLE condition experienced significantly lower extraneous cognitive load compared to those in the conventional VLE condition. Similarly, a significant difference was found for germane cognitive load, $t(63) = 4.44$, $p < 0.001$, with a large effect size ($d = 1.10$), suggesting that prompting strategies effectively promoted deeper cognitive processing. No significant difference was observed for intrinsic cognitive load, $t(63) = 0.10$, $p = 0.921$, confirming that both groups faced comparable inherent task difficulty. These findings provide strong evidence that the prompting intervention successfully reduced unnecessary cognitive processing while enhancing meaningful learning engagement.

Comprehension Performance

To assess the impact of prompting strategies on students' comprehension of biography texts, an independent samples t-test was conducted comparing the posttest comprehension scores of both groups. The results are presented in Table 4.

Table 4. Independent Samples t-Test Results for Comprehension Scores

Group	n	Mean (M)	Standard Deviation (SD)	t-value	df	p-value	Effect Size (Cohen's d)
Experimental	32	16.7	2.3	4.96	63	< 0.001*	1.24
Control	33	13.4	3.0				

The experimental group achieved significantly higher comprehension scores (M = 16.7, SD = 2.3) compared to the control group (M = 13.4, SD = 3.0), $t(63) = 4.96$, $p < 0.001$. The effect size (Cohen's d = 1.24) indicates a very large practical significance, suggesting that the integration of prompting strategies in the VLE had a substantial positive impact on students' ability to comprehend biography texts. This finding is consistent with the cognitive load results, reinforcing the notion that reducing extraneous load and enhancing germane load through effective prompting leads to improved learning outcomes.

Relationship Between Cognitive Load and Comprehension

To examine the relationship between cognitive load dimensions and comprehension performance, a multiple regression analysis was conducted with comprehension score as the dependent variable and the three cognitive load dimensions (intrinsic, extraneous, and germane load) as independent variables. Table 5 presents the regression coefficients and model summary.

Table 5. Multiple Regression Analysis: Cognitive Load Predicting Comprehension Scores

Predictor	Unstandardized Coefficient (B)	Standard Error (SE)	Standardized Coefficient (β)	t-value	p-value
(Constant)	12.45	2.18		5.71	< 0.001
Intrinsic Load	-0.15	0.28	-0.06	-0.54	0.592
Extraneous Load	-1.28	0.24	-0.42	-5.33	< 0.001*
Germane Load	1.19	0.25	0.39	4.76	< 0.001*

Model Summary:

R	R^2	Adjusted R^2	F-statistic	df	p-value
0.72	0.52	0.49	21.67	(3, 61)	< 0.001*

The regression model was statistically significant, $F(3, 61) = 21.67$, $p < 0.001$, explaining 52% of the variance in comprehension scores ($R^2 = 0.52$, Adjusted $R^2 = 0.49$). Extraneous cognitive load emerged as a significant negative predictor of comprehension (β = -

0.42, $p < 0.001$), indicating that higher levels of extraneous load were associated with lower comprehension performance. Conversely, germane cognitive load was a significant positive predictor ($\beta = 0.39$, $p < 0.001$), suggesting that greater germane load contributed to better comprehension. Intrinsic cognitive load was not a significant predictor ($\beta = -0.06$, $p = 0.592$), confirming that the inherent complexity of the biography texts did not differentially affect comprehension across groups.

These findings underscore the critical role of instructional design in managing cognitive load. Specifically, the results suggest that prompting strategies optimized the VLE by reducing extraneous cognitive demands and redirecting cognitive resources toward meaningful learning processes, ultimately enhancing students' comprehension of biography texts.

DISCUSSION

The findings of this study provide compelling evidence for the effectiveness of prompting strategies in optimizing VLEs to reduce students' cognitive load in biography text learning. Students in the prompting-enhanced VLE condition reported significantly lower extraneous cognitive load and higher germane cognitive load compared to those in the conventional VLE condition, with correspondingly superior comprehension performance.

Reduction of Extraneous Cognitive Load

The significant reduction in extraneous cognitive load observed in the experimental group aligns with previous research demonstrating that well-designed prompts can guide learners' attention and reduce unnecessary cognitive processing (Wang et al., 2024; Zeitlhofer et al., 2023). In the context of biography text learning, process-oriented prompts appeared to help students navigate the complex informational landscape of biographical narratives by signaling what information was most relevant and how different elements connected. This finding is consistent with the attentional guidance mechanism described by Wen et al. (2024), which suggests that prompts function as cognitive scaffolds that reduce the need for learners to independently determine what to attend to in complex multimedia environments.

Enhancement of Germane Cognitive Load

The higher germane cognitive load reported by the experimental group is particularly noteworthy. Germane load represents the cognitive effort devoted to schema construction and meaningful learning (Sweller, 2023). The finding that prompting strategies increased germane load suggests that prompts not only reduced unnecessary processing but also redirected cognitive resources toward deeper engagement with the material. This is consistent with research on self-explanation prompts, which have been shown to enhance learning performance by encouraging learners to elaborate on and integrate new information (Wang & Guang, 2024; Lee et al., 2024).

The distinction between process-oriented and content-oriented prompts appears to be meaningful in this context. Process-oriented prompts, which guided students through analytical procedures, likely contributed to reduced extraneous load by providing clear cognitive pathways through the text. Content-oriented prompts, which directed attention to specific

information, may have enhanced germane load by encouraging deeper processing of key content. This dual function of prompts (reducing extraneous load while enhancing germane load) represents an optimal instructional design outcome (Triana-Vera & López-Vargas, 2025; Li et al., 2025).

Implications for VLE Design

These findings have significant implications for the design of VLEs for literacy instruction. First, they suggest that VLE optimization should not focus solely on technological features but should prioritize instructional scaffolding through embedded prompts. Second, they indicate that different types of prompts serve different cognitive functions, suggesting that instructional designers should strategically deploy both process-oriented and content-oriented prompts based on learning objectives. Third, they demonstrate that prompting strategies can be effectively integrated into existing VLE platforms without requiring substantial technological overhauls, making them a cost-effective intervention for improving learning outcomes.

The findings also contribute to the broader literature on cognitive load in digital learning environments. Previous research has highlighted the tendency of VLEs to impose extraneous cognitive load due to interface complexity and information overload (Costley, 2020; Rahmat et al., 2022). This study demonstrates that systematic prompting can mitigate these negative effects, supporting the argument that cognitive load is not an inherent property of VLEs but rather a function of instructional design quality (Sweller & Roussel, 2022; Faber et al., 2024).

Limitations and Future Research

Several limitations should be acknowledged. First, the study was conducted with secondary school students in a specific cultural and educational context, limiting generalizability to other populations. Second, the intervention was relatively brief (four weeks), and the long-term effects of prompting strategies on cognitive load and learning outcomes remain unclear. Third, the study relied on self-report measures of cognitive load, which, while widely used, may be subject to response biases. Future research should incorporate objective measures of cognitive load, such as physiological indicators or think-aloud protocols, to complement self-report data. Additionally, longitudinal studies examining the sustained effects of prompting strategies and investigations of prompting effectiveness across different text types and learning domains would further strengthen the evidence base.

CONCLUSION

This study demonstrates that optimizing Virtual Learning Environments through prompting strategies significantly reduces students' extraneous cognitive load and enhances germane cognitive load in biography text learning, with corresponding improvements in comprehension performance. These findings underscore the critical role of instructional design in maximizing the educational potential of VLEs and offer practical guidance for educators and

instructional designers seeking to balance technological affordances with cognitive constraints. As VLEs continue to proliferate in educational contexts, intentional integration of evidence-based prompting strategies represents a promising pathway toward more effective and cognitively sustainable digital learning experiences.

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