



Content English Integrated Mathematics Learning with Reduced Split Attention: A Cognitive Load Approach

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Received: 04/08/2026	ABSTRACT Integrating language and mathematical content in classroom instruction can support both conceptual understanding and academic English development. However, poorly designed instructional materials may increase unnecessary cognitive load, particularly when learners must divide their attention across multiple sources of information. Based on Cognitive Load Theory, this study examines the effects of Content and English Integrated Mathematics Learning and reduced split attention design on students' cognitive load in mathematics learning. This study employed a 2 × 2 factorial experimental design involving four classes. The first factor was the instructional approach: Content and English Integrated Mathematics Learning and Mathematics Learning without language integration. The second factor was instructional material design: Reduced Split Attention and Split Attention. Accordingly, four groups were implemented: (A) Content and English Integrated Mathematics Learning with Reduced Split Attention, (B) Mathematics Learning with Reduced Split Attention, (C) Content and English Integrated Mathematics Learning with Split Attention, and (D) Mathematics Learning with Split Attention. Cognitive load data were collected using a mental effort questionnaire. The results indicate that reduced split attention significantly decreases extraneous cognitive load compared with split
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attention materials. Furthermore, integrating English and mathematical content does not increase cognitive load when instructional materials are carefully designed to minimize split attention. These findings highlight the importance of instructional design in supporting effective content–language integration in mathematics learning.

Keywords: Content Language Integrated Learning, Mathematics Learning, Split Attention, Cognitive Load Theory

Introduction

The increasing globalization of education has positioned English as a crucial medium for accessing scientific knowledge and participating in academic discourse. Consequently, educational systems are encouraged to integrate language and content learning to prepare students for global academic demands. One of the most prominent approaches addressing this need is Content and Language Integrated Learning (CLIL), which integrates subject matter and language learning within a unified instructional process (Coyle et al., 2010; Dalton-Puffer, 2011). Rather than treating language as a separate subject, CLIL positions language as a medium for learning content, thereby fostering simultaneous development of conceptual understanding and language proficiency (Llinares et al., 2012; Cenoz et al., 2014).

A growing body of research has highlighted the benefits of CLIL in improving students' academic performance, motivation, and cognitive engagement (Lasagabaster & Sierra, 2010; Pérez-Cañado, 2012; Ruiz de Zarobe, 2013; Bruton, 2013). Recent studies also confirm that CLIL remains relevant in contemporary education, showing positive effects on vocabulary development, procedural knowledge, and student engagement, although its effectiveness varies depending on instructional quality and context (López-Medina & Casado, 2024; Lai, 2024; Zhang et al., 2024). These findings indicate that the success of CLIL is not solely determined by the integration of language and content, but also by how instruction is designed and implemented.

Despite its potential benefits, the integration of language and content introduces additional cognitive demands. Mathematics, as a discipline, is inherently abstract and requires high levels of symbolic reasoning and conceptual understanding (Arcavi, 2003; Schoenfeld, 2016). Students must coordinate multiple representations, including symbols, graphs, numerical data, and verbal explanations (Ainsworth, 2006; Duval, 2006). When English is introduced as an additional layer, students are required to process both linguistic and mathematical information simultaneously, which may increase cognitive demands and lead to cognitive overload (Prediger et al., 2015; Moschkovich, 2012).

From the perspective of Cognitive Load Theory, learning is constrained by the limited capacity of working memory (Sweller, 1988; Sweller et al., 2011). Cognitive Load Theory distinguishes between intrinsic cognitive load, extraneous cognitive load, and germane cognitive load (Paas et al., 2003; de Jong, 2010; Kalyuga, 2011; Mayer, 2009). Among these, extraneous cognitive load is particularly critical because it is directly influenced by instructional design and

can be minimized to improve learning efficiency (Sweller et al., 2019). Recent studies also confirm that ineffective instructional design can increase unnecessary cognitive load and hinder learning outcomes (Jiang & Wang, 2023).

One of the most significant sources of extraneous cognitive load is the split attention effect, which occurs when learners must divide their attention between multiple sources of information that need to be mentally integrated (Chandler & Sweller, 1991). This condition forces learners to expend additional cognitive resources on integrating information rather than understanding the content itself (Tarmizi & Sweller, 1988; Mousavi et al., 1995). Numerous studies have demonstrated that split attention negatively affects learning efficiency, particularly in complex domains such as mathematics (Ayres & Sweller, 2014; Ginns, 2006). Recent research also indicates that fragmented information presentation in digital and multimodal learning environments continues to increase cognitive load and reduce learning performance (Liu et al., 2023; Hamed & Rebello, 2026).

To address this issue, the reduced split attention strategy has been proposed as an effective instructional design approach. This strategy integrates multiple sources of information into a single, coherent representation, thereby reducing the need for mental integration (Ayres, 2006; Kalyuga et al., 1999). Empirical evidence consistently shows that reduced split attention can significantly decrease extraneous cognitive load and improve learning outcomes (Ginns, 2006; Schroeder & Cenkci, 2018; Sweller et al., 2019).

However, despite extensive research on CLIL and cognitive load theory, there remains a significant gap in the literature. First, most CLIL studies focus on language outcomes, motivation, or general achievement, with limited attention to cognitive load as a key explanatory variable. Second, research on cognitive load and split attention has largely been conducted in monolingual contexts, without considering the additional complexity introduced by language integration. Third, there is still limited empirical evidence examining the interaction between CLIL and instructional design strategies such as reduced split attention, particularly in mathematics learning.

This gap is particularly important in the context of statistical topics such as correlation and linear regression, which require both procedural calculations and conceptual interpretation (Garfield & Ben-Zvi, 2008; Chance et al., 2007). These topics impose high intrinsic cognitive load, and when combined with language integration and suboptimal instructional design, may exceed students' cognitive capacity and hinder learning.

Therefore, this study aims to investigate the effects of Content and English Integrated Mathematics Learning and reduced split attention design on students' cognitive load in mathematics learning. Using a 2×2 factorial experimental design, this study examines both the main effects and the interaction effect

between instructional approach and instructional material design, contributing to the development of more effective and cognitively efficient mathematics learning.

Research Methods

This study employed a true experimental design with a 2×2 factorial structure grounded in Cognitive Load Theory to investigate the effects of instructional approach and instructional material design on students' cognitive load in mathematics learning. The factorial design enabled the examination of both the main effects and the interaction effect between the two independent variables. The first factor was the instructional approach, consisting of Content and English Integrated Mathematics Learning and Mathematics Learning without language integration. The second factor was instructional material design, consisting of Reduced Split Attention and Split Attention conditions.

The study was conducted in a public senior high school in Indonesia with an A accreditation level, located in the capital of a regency. This school was selected due to its relatively stable academic performance and adequate learning facilities, which support the implementation of experimental instructional designs. The participants of this study were 80 students selected through cluster random sampling from four intact classes. Each class consisted of 20 students and was randomly assigned to one of the four experimental groups. Group A received Content and English Integrated Mathematics Learning with Reduced Split Attention, Group B received Mathematics Learning with Reduced Split Attention, Group C received Content and English Integrated Mathematics Learning with Split Attention, and Group D received Mathematics Learning with Split Attention. Prior to the treatment, a pre-test was administered to assess students' prior knowledge in statistics, particularly in correlation and regression. The pre-test results were analyzed to ensure that there were no significant differences among the groups, indicating initial equivalence.

The instructional materials were developed based on principles of cognitive load, particularly focusing on the split attention effect. In the Reduced Split Attention condition, instructional materials were designed by integrating all relevant information, including formulas, explanations, and examples, into a single, coherent representation to minimize extraneous cognitive load. In contrast, in the Split Attention condition, related information was presented in separate formats, such as placing formulas and explanations in different locations, requiring students to divide their attention and actively integrate the information.

The instructional intervention was conducted over two meetings, each lasting approximately 90 minutes. In the first meeting, students learned how to calculate the Pearson correlation coefficient and interpret its magnitude and

direction within the context of linear regression analysis. In the second meeting, students learned how to calculate the coefficient of determination and interpret its meaning in explaining the proportion of variance in the dependent variable accounted for by the independent variable. All groups received the same mathematical content and followed the same instructional sequence, including explanation, worked examples, guided practice, and independent practice.

The differences among the groups were limited to the instructional approach and material design. In the Content and English Integrated Mathematics Learning groups, instruction was delivered using English integrated with mathematical explanations to facilitate simultaneous development of content understanding and language proficiency. In contrast, in the non-integrated groups, instruction was delivered using the students' native language without English integration. The duration, learning objectives, and tasks were controlled across all groups to ensure internal validity.

Data on students' cognitive load were collected using a subjective mental effort rating scale. The instrument employed a 9-point scale, ranging from 1 (very, very easy) to 9 (very, very difficult), in which students rated the amount of mental effort required to understand the learning material. Lower scores indicated lower cognitive load, while higher scores indicated higher cognitive load. The questionnaire was administered at the end of each instructional session to capture students' immediate perception of the cognitive demands during learning. Students were instructed to focus on the mental effort required rather than their performance outcomes. This measure primarily reflects extraneous cognitive load associated with instructional design.

To ensure the validity of the instrument, the questionnaire was reviewed by experts in mathematics education and educational psychology. A pilot test was also conducted prior to the main study to evaluate the clarity and consistency of the instrument.

The collected data were analyzed using two-way analysis of variance (ANOVA) to examine the main effects of instructional approach and instructional material design, as well as their interaction effect on students' cognitive load. Prior to hypothesis testing, assumption tests including normality (Kolmogorov–Smirnov test) and homogeneity of variance (Levene's test) were conducted. All statistical analyses were performed at a significance level of 0.05.

Results

Mathematics Learning Outcomes

The assessment of mathematics learning outcomes was based on test scores

administered after the treatment. Descriptively, the mean score of students who learned through Content and English Integrated Mathematics Learning with Reduced Split Attention (Group A) was higher ($M = 85.40$; $SD = 4.85$) compared to students who learned through Mathematics Learning with Reduced Split Attention (Group B) ($M = 82.15$; $SD = 5.10$). Meanwhile, students who learned through Content and English Integrated Mathematics Learning with Split Attention (Group C) obtained a mean score of ($M = 76.30$; $SD = 5.75$), which was higher than students in Mathematics Learning with Split Attention (Group D) ($M = 73.25$; $SD = 6.20$).

The results of inferential analysis using two-way ANOVA revealed a significant effect of instructional material design on mathematics learning outcomes ($F(1,76) = 26.05$; $p < 0.001$). This indicates that students who learned using Reduced Split Attention achieved higher learning outcomes than those who learned using Split Attention. However, there was no significant difference in mathematics learning outcomes in terms of instructional approach ($F(1,76) = 2.14$; $p = 0.148$). This suggests that the integration of English in mathematics learning does not have a direct significant effect on students' learning outcomes.

Furthermore, the analysis revealed a significant interaction effect between instructional approach and instructional material design ($F(1,76) = 6.59$; $p = 0.012$). This indicates that the effectiveness of integrating language and content in mathematics learning is influenced by how the instructional materials are designed, particularly in reducing split attention.

Cognitive Load

Descriptively, students who learned using Reduced Split Attention tended to experience lower cognitive load compared to those who learned using Split Attention. Students in Group A had a mean cognitive load of ($M = 3.20$; $SD = 0.85$), and Group B ($M = 3.05$; $SD = 0.90$). Meanwhile, students in Group C had a mean of ($M = 5.75$; $SD = 1.10$), and Group D ($M = 5.40$; $SD = 1.20$).

The results of inferential analysis showed a significant difference in cognitive load based on instructional material design ($F(1,76) = 44.35$; $p < 0.001$). This indicates that the use of Reduced Split Attention significantly reduces students' cognitive load compared to Split Attention. Meanwhile, there was no significant difference in cognitive load in terms of instructional approach ($F(1,76) = 1.72$; $p = 0.194$). This suggests that integrating English into mathematics learning does not directly increase students' cognitive load.

However, the analysis also revealed a significant interaction effect between instructional approach and instructional material design on cognitive load ($F(1,76) = 6.09$; $p = 0.016$). This indicates that the effect of language integration on cognitive load depends on the design of the instructional materials used.

Interaction Effect of Instructional Approach and Material Design on Cognitive Load

The results of the analysis indicate a significant interaction effect between instructional approach and instructional material design on cognitive load ($F(1,76) = 6.09$; $p = 0.016$). To further illustrate this interaction, the estimated marginal means are presented in Figure 1.

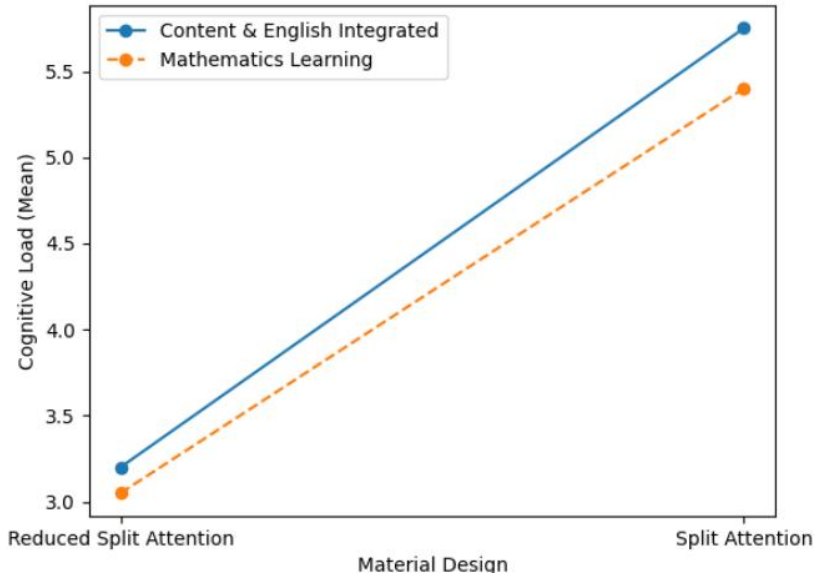


Figure 1. Interaction Effect of Instructional Approach and Material Design on Cognitive Load

Based on Figure 1, it can be observed that cognitive load increases under the Split Attention condition compared to the Reduced Split Attention condition across both instructional approaches. However, the pattern of increase differs between the groups, indicating the presence of an interaction effect.

In the Reduced Split Attention condition, the difference in cognitive load between Content and English Integrated Mathematics Learning and Mathematics Learning is relatively small. This suggests that when instructional materials are well-integrated, the addition of English does not substantially increase students' cognitive load.

In contrast, in the Split Attention condition, the gap becomes more pronounced, where students in the Content and English Integrated Mathematics Learning group experience higher cognitive load compared to those in the Mathematics Learning group. This indicates that when instructional materials are poorly designed and require learners to divide their attention, the integration of language adds an extra cognitive burden.

Furthermore, the non-parallel pattern of the lines in the graph confirms the

presence of an interaction effect. This finding suggests that the impact of instructional approach on cognitive load is dependent on the design of instructional materials. In other words, the effectiveness of integrating English into mathematics learning is strongly influenced by whether the instructional design minimizes split attention.

Overall, these results indicate that Reduced Split Attention plays a crucial role in managing cognitive load, particularly in learning environments that integrate both content and language.

Discussion

The findings of this study demonstrate that instructional material design, particularly the use of Reduced Split Attention, plays a critical role in improving mathematics learning outcomes and reducing cognitive load. The significant effect of material design on both learning outcomes and cognitive load confirms that how information is presented is a determining factor in learning effectiveness. This result is consistent with studies showing that fragmented instructional materials increase unnecessary cognitive processing, thereby reducing learning efficiency (Ayres & Sweller, 2014; Ginns, 2006).

From the perspective of Cognitive Load Theory, this finding can be explained by the reduction of extraneous cognitive load. When students are required to split their attention between multiple sources of information, additional cognitive resources are allocated to integrating these sources rather than understanding the content itself. Previous research confirms that split-attention conditions significantly increase cognitive load, particularly in tasks with high element interactivity such as mathematics problem solving (Sweller et al., 2011; Kalyuga, 2011). Therefore, the use of integrated instructional materials allows students to focus their cognitive resources on meaningful learning processes, resulting in higher achievement.

In contrast, the results indicate that the instructional approach (Content and English Integrated Mathematics Learning) does not have a significant direct effect on learning outcomes or cognitive load. This finding aligns with meta-analytic evidence suggesting that CLIL produces learning outcomes that are comparable, rather than superior, to traditional instruction (Zhang et al., 2024). This suggests that the effectiveness of CLIL is not inherent in the approach itself but depends on supporting instructional conditions.

However, the most important finding of this study lies in the significant interaction effect between instructional approach and material design. The results indicate that the integration of English into mathematics learning does not increase

cognitive load when instructional materials are well-designed (Reduced Split Attention). Conversely, when instructional materials are poorly designed (Split Attention), language integration contributes to increased cognitive load. This finding is supported by research demonstrating that cognitive load is influenced not only by task complexity but also by the interaction between learner characteristics and instructional design (Seufert, 2020; Sweller et al., 2019).

Furthermore, studies in multimedia and bilingual learning contexts indicate that language processing and visual complexity jointly influence cognitive load. When learners are required to process both linguistic and visual information simultaneously, poorly designed materials can significantly increase cognitive demands (Mayer, 2009; Sweller et al., 2011). This explains why students in the Split Attention condition experienced higher cognitive load, particularly in the Content and English Integrated groups.

The interaction pattern observed in this study also reinforces findings from CLIL research, which emphasize that the success of language-integrated learning depends on instructional support and scaffolding (Coyle et al., 2010; Dalton-Puffer, 2011). Without appropriate instructional design, CLIL may impose additional cognitive demands that hinder learning. However, when supported by effective design strategies such as reduced split attention, CLIL can be implemented without increasing cognitive load.

These findings have important implications for mathematics instruction. First, they highlight that reducing extraneous cognitive load should be a primary consideration in instructional design, particularly in complex topics such as correlation and regression. Second, they suggest that integrating language and content in mathematics learning is feasible and beneficial, provided that instructional materials are carefully designed to support cognitive processing. Third, the results emphasize that instructional design acts as a moderating variable that determines whether language integration becomes a support or a burden for learners.

In conclusion, this study contributes to the literature by demonstrating that the effectiveness of Content and English Integrated Mathematics Learning is not determined solely by the integration of language and content, but by how instructional materials are designed to manage cognitive load. The findings provide empirical evidence that Reduced Split Attention is a key strategy for optimizing both learning outcomes and cognitive efficiency in mathematics education.

Conclusion

This study aimed to examine the effects of instructional approach (Content

and English Integrated Mathematics Learning) and instructional material design (Reduced Split Attention vs. Split Attention) on students' mathematics learning outcomes and cognitive load. The findings indicate that instructional material design plays a more decisive role than the instructional approach itself.

Specifically, the use of Reduced Split Attention significantly improves mathematics learning outcomes and reduces students' cognitive load compared to Split Attention. This confirms that well-integrated instructional materials help students allocate their cognitive resources more effectively for meaningful learning. In contrast, the instructional approach, namely the integration of English into mathematics learning, does not have a direct significant effect on either learning outcomes or cognitive load.

However, the most important contribution of this study lies in the significant interaction between instructional approach and material design. The results show that language integration does not increase cognitive load when supported by well-designed instructional materials. Conversely, when instructional materials are poorly designed, language integration may impose additional cognitive demands on students. This finding highlights that instructional design functions as a critical moderating factor in determining the effectiveness of Content and English Integrated Mathematics Learning.

In conclusion, this study provides empirical evidence that optimizing instructional material design, particularly through the reduction of split attention, is essential for enhancing both learning outcomes and cognitive efficiency in mathematics education. The findings suggest that integrating language and content is pedagogically feasible, provided that instructional materials are carefully designed to manage cognitive load. Therefore, educators are encouraged to prioritize coherent and integrated instructional design when implementing language-integrated approaches in mathematics classrooms.

Author Contributions

Iskandar: Conceptualization, methodology, instructional material design, data collection, formal analysis, investigation, writing-original draft preparation, and supervision.

Metria Dicky Putra: Methodology, validation, data analysis, visualization, writing-review and editing, and interpretation of results.

Amon Bernabas Tenis: Data collection, resources, investigation, project administration, validation, and writing-review and editing.

All authors contributed to the study conception and design, discussed the results, reviewed the manuscript, and approved the final version of the manuscript for publication.

Ethical Statement

This study involved human participants and was conducted in accordance with ethical standards for educational research. Participation was voluntary, and informed consent was obtained from all participants and/or their legal guardians prior to data collection. Participants were assured that their responses would be treated confidentially and used solely for research purposes. No personally identifiable information was disclosed in this study.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Declaration of generative AI and AI-assisted technologies

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with language editing, grammar improvement, and manuscript refinement. The authors carefully reviewed, revised, and validated all content generated with the assistance of this tool and take full responsibility for the accuracy and integrity of the final manuscript.

IN THE WRITING PROCESS

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