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# The Impact of Cognitive Load on Learning Achievement and Semester Level in Mathematics Education Students


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**Abstract:** This study examined the impact of cognitive load on learning achievement and academic progression in mathematics education students, focusing on a novel investigation into how different types of cognitive load interact with student performance. This study analyzed data from 158 mathematics education students at three private universities using a survey method combined with a quantitative approach. Descriptive statistics, correlation analysis, and one-way ANOVA were used to investigate the relationships between intrinsic, extrinsic, and germane cognitive load, students' academic achievement, and semester level. The findings revealed significant descriptive differences in the mean levels across the three types of cognitive load. However, the correlation analysis revealed a statistically insignificant positive relationship between cognitive load and math learning achievement, indicating that differences in cognitive load had no significant impact on students' learning outcomes in mathematics courses. Furthermore, the ANOVA results showed that semester level had no significant effect on the cognitive load of students. These findings add to the ongoing discussion on cognitive load theory, emphasizing the importance of instructional strategies that balance and optimize cognitive load in mathematics education. This study is unique in that it investigates how various types of cognitive loads —intrinsic, extrinsic, and germane—affect students’ academic performance and progression in mathematics education.

**Keywords**: cognitive load; learning achievement; semester level

# 認知負荷对学生在数学教育中的表现和学期程度的影响

**摘要**：本研究探討認知負荷對數學教育學生的學習成就和學業進步的影響，著重於不同類型的認知負荷如何與學生的表現互動的新穎調查。本研究使用調查方法結合定量方法，分析三所私立大學158名數學教育學生的資料。研究使用描述性統計、相關分析和單向方差分析來探討內在認知負荷、外在認知負荷和種族認知負荷、學生的學業成績和學期水準之間的關係。研究結果顯示，三種認知負荷的平均值有顯著的描述性差異。然而，相關分析顯示認知負荷與數學學習成就之間的正向關係在統計學上並不顯著，顯示認知負荷的差異對學生的數學課程學習成果沒有顯著的影響。此外，方差分析結果顯示學期等級對學生的認知負荷沒有顯著的影響。這些研究結果增加了認知負荷理論的持續討論，強調在數學教育中平衡和優化認知負荷的教學策略的重要性。本研究的獨特之處在於它調查了各種類型的認知負荷-內在負荷、外在負荷和德文負荷 - 如何影響學生在數學教育中的學業成績和進步。

**关键词**：認知負荷; 學習成績; 學期程度

## 1. Introduction

Mathematics is regarded as a difficult subject for the majority of students [1-3] and is also an important subject in the development of literacy and problem-solving [4-6]. Many students struggle to understand mathematical concepts and perform satisfactorily during this course [7-9]. The challenges encountered by students with learning disabilities in mathematics, specifically in the realm of word problem-solving, necessitate focused interventions, clear instruction, and a comprehensive understanding of the particular domains in which they may encounter difficulties [10-12]. Lessons in college mathematics classrooms frequently focus on theoretical concepts and repetitive tasks, limiting students’ abilities to apply mathematical principles in practical scenarios. To improve students’ ability to apply mathematical principles in real-life situations, instructors in college mathematics classrooms should consider incorporating concrete subjects, utilizing technology, developing social and emotional intelligence, and implementing innovative teaching methods as a strategy to overcome the limitations imposed by abstract concepts and repetitive exercises [13, 14].

Previous research has shown that student achievement in mathematics is influenced by teaching methods, intelligence, motivation, stress/cognitive load, and learning environment [15-18]. Furthermore, students’ perceptions of teacher competence, problem-solving ability, and mathematical connection ability have been shown to influence learning achievement in mathematics either directly or indirectly. Overall, these findings emphasize the significance of considering a variety of factors. However, one aspect that is increasingly drawing the attention of researchers in this context is the cognitive load students experience during the mathematics learning process.

Cognitive load refers to the mental effort required to process information during learning [19-25]. There are three types of cognitive load: intrinsic, extraneous, and germane [23], [25-28]. Load Intrinsically: This refers to the inherent difficulty of the material being learned, such as its complexity. Extraneous Load: This cognitive load imposed by an instructional method or materials that are not required, such as irrelevant information or poorly designed instruction. Germane load is a cognitive load that is directly related to the learning task and contributes to schema construction, which is the formation of mental models that help learners understand and remember.

Various factors can influence cognitive load, such as instructional strategy, task difficulty, and prior knowledge [26, 29, 30]. Instructional design plays a crucial role in managing cognitive load [31, 32]. Prior knowledge can impact cognitive load, as seen in a study using pupil dilation and heart rate variability to diagnose changing cognitive load in learners [26]. Task difficulty, intrinsic to the learning task, is a key factor affecting cognitive load, as highlighted in the cognitive load theory, which focuses on the load imposed on working memory during learning tasks [30]. Understanding these factors is essential for optimizing learning processes and enhancing performance on various cognitive tasks.

Cognitive load research in mathematics education has extensively explored how the human mind handles mathematical information and the factors that influence learning and problem solving [24, 33]. Incorporating questioning activities while reading historical mathematics texts can significantly reduce cognitive load and support assimilation of new information [34]. Mimicking tracking actions can help reduce cognitive load in mathematics learning and improve performance, motivation, and outcomes for young children [35]. Instructional designers and teachers can use cognitive load theory to help students process information more effectively [23, 26, 28]. Teachers can help their students learn more by understanding the three types of cognitive load and devising strategies to reduce extraneous load while increasing the germane load.

Cognitive load in mathematics learning can be related to the complexity of concepts, problem-solving tasks, or the manner in which the lecturer presents the material.

Research on cognitive load in students has explored various aspects, such as the impact of testing modes on performance, student engagement, learning self-regulation, and learning achievement [36-40], patterns of cognitive burden in engineering students [41], and authorship verification in educational settings [42]. Although research has been conducted on this topic, several gaps remain in our understanding of how cognitive load specifically influences student achievement in mathematics courses in the context of mathematics education. This research aims to fill this gap in the literature by conducting an in-depth empirical study to explore the cognitive load of mathematics education students, the influence of cognitive load on student achievement, and the significance of differences in cognitive load for students across semester levels in mathematics courses.

## 2. Literature Review

### 2.1. Cognitive Load in Mathematics Learning

Understanding the cognitive load in the context of mathematics learning is critical, as mathematics is frequently regarded as a subject requiring sophisticated cognitive processing. The cognitive load in mathematics education refers to the mental resources required to process mathematical information and concepts. [21, 43]. This includes understanding concepts, following rules and procedures, and resolving issues. Many factors influence cognitive load in mathematics, including element interactivity, practice effects, instructional strategies, task difficulty, and prior knowledge [44, 45]. Task complexity in learning tasks is determined by element interactivity, which considers information structure and long-term memory knowledge [46]. According to the cognitive load theory, human working memory is limited. When this limit is exceeded, the learning process becomes inefficient and students' comprehension of the material learned may suffer [47, 48]. In the context of mathematics education, this means that if the teacher presents a large number of concepts and formulas simultaneously, students may become overwhelmed and unable to comprehend the material [49, 50].

Cognitive load comprises intrinsic, extraneous, and germane components, all of which are critical for effective instructional design [24, 51]. Intrinsic cognitive load is proportional to the complexity of the material under study. Problem-solving or understanding abstract concepts in mathematics, for example, frequently necessitates a high intrinsic cognitive load. Several studies have found that effective mathematics learning necessitates the effective management of intrinsic cognitive load, such as presenting material in stages and providing clear guidance to students [52]. Extrinsic cognitive load refers to external factors that can influence the learning process, such as the layout of the information in a textbook or classroom setting. In mathematics education, improper use of media or technology can increase the extrinsic cognitive load and interfere with students' understanding of the material [53-55]. Appropriate technology selection and learning design that account for cognitive load can help improve learning effectiveness and reduce barriers caused by cognitive overload. As a result, educators must pay close attention to how technology is used in the learning context to reduce unnecessary cognitive load and support optimal learning outcomes. Finally, germane cognitive load refers to the cognitive effort required to process and integrate information to achieve deep understanding. In mathematics, a germane cognitive load can occur when students are presented with situations that necessitate creative thinking or problem-based learning. Understanding the role of the germane cognitive load in the learning process allows educators to create more effective learning experiences that support students' cognitive development in understanding complex mathematical concepts.

Understanding the cognitive load in mathematics learning is critical for optimizing instructional strategies and increasing student performance in cognitively demanding subjects. Several studies have emphasized the importance of managing cognitive load in mathematics learning. Learning strategies with clear guidance and structured steps can help reduce students' cognitive load [56, 57], which improves their understanding of mathematical concepts. Effective learning strategies, motivation, and prior knowledge, as well as learning design, can all have an impact on the cognitive load in math learning [44, 58, 59]. An active learning approach that encourages students to solve problems or discover concepts on their own can increase the cognitive load while improving concept understanding.

### 2.2. Cognitive Load and Learning Achievement

Cognitive load plays a critical role in determining the success of a learning process. This concept refers to the total mental effort required to process information acquired during the learning process. Educational research has extensively examined the relationship between cognitive load and learning achievements in mathematics. The Cognitive Load Theory (CLT) has been instrumental in understanding how various types of cognitive load, such as intrinsic, extraneous, and germane, influence learning effectiveness. [44, 47, 51]. Germane cognitive load is positively related to learning outcomes [58]. This demonstrates that when students engage in creative thinking or problem-based learning in a mathematical context, the resulting germane cognitive load contributes to better learning outcomes. Instructional strategy, task difficulty, and prior knowledge have an impact on cognitive load and mathematical problem-solving performance [51]. This finding emphasizes the significance of the cognitive load in influencing learning outcomes in mathematics education. The effects of cognitive load on students' learning processes and academic outcomes are critical aspects of education. Several studies have investigated this relationship, providing valuable insights into effective strategies and interventions for students to manage their cognitive load. [42, 60].

Optimal cognitive load can promote effective learning, whereas excessive or insufficient cognitive load can impair students' ability to process and apply information in relevant contexts. When students are presented with overly complex math problems, their cognitive load rises, and their performance in math tasks declines. [39, 44, 61]. Understanding these dynamics is critical for educators who want to improve their learning environment and help students manage their cognitive load effectively. Cognitive load is an important factor in determining the success of a learning process [44]. To improve learning outcomes, educators must attempt to optimize the cognitive load. This can be accomplished by creating learning materials that consider the 'complexity of the material as well as the students' working memory capacity. For example, by breaking down complex materials into smaller parts and ranking them from the simplest to the most complex, students can gradually increase their understanding [49, 52]. The use of examples and illustrations in education can also help reduce cognitive load and improve student comprehension [62, 63]. Examples and illustrations can help students to understand abstract and complex concepts by providing concrete mental images. Technology can also help reduce cognitive load and improve learning outcomes [23, 64]. Multimedia can help students to understand complex and abstract concepts by presenting information in visual and audio formats. This demonstrates that using appropriate strategies, illustrations, and technology can help students process information more efficiently, improve comprehension, and ultimately improve academic achievement.

Furthermore, the relationship between cognitive load and learning achievement is not always linear [23, 64]. This means that a high cognitive load does not always prevent learning, and vice versa. Good understanding and learning achievement do not always result from a low cognitive load. A low cognitive load can also impede learning [65, 66]. When students are not adequately challenged, they may not develop a thorough understanding of mathematical concepts or the skills required to apply these concepts in new contexts. Research emphasizes the complex interplay between emotional states, cognitive processes, and learning outcomes [67, 68]. When analyzing academic performance, it is important to adopt a holistic approach. Although cognitive load plays an important role in learning and academic achievement, it is influenced by a number of variables, such as emotional state, motivation, self-directed learning, and anxiety. Understanding this multifaceted relationship is essential for creating effective educational strategies to promote optimal learning outcomes.

### 2.3. Cognitive Load and Semester Level

The relationship between cognitive load and academic development and educational level in mathematics learning has piqued the interest of educational researchers. Managing cognitive load is critical for effective learning, particularly in complex tasks [69]. In general, cognitive load increases with the level of material difficulty and task complexity. Students face varying challenges in terms of cognitive load as they progress through education. Students in junior secondary education may have limited math skills, resulting in a high cognitive load when learning basic math concepts. Students at higher education levels may be exposed to more abstract materials or complex concepts, thereby increasing their cognitive load.

Previous learning experiences can also influence how students manage their cognitive loads. Students with a solid mathematical foundation may be better able to handle higher cognitive loads than less-experienced students. This is because students with a strong understanding of math concepts can process information and solve mathematical problems more efficiently. This is supported by research demonstrating that basic math skills can influence how students manage their cognitive load while completing math tasks [70]. There was no significant correlation between academic semesters and stress level [71]. This suggests that while external factors such as stress can influence cognitive load, academic development is not always a direct predictor. Students gradually develop the knowledge and skills required to cope with the increasing cognitive load as they progress through their education. This knowledge and skills, also known as fundamental or prior knowledge, can help reduce cognitive load and facilitate the learning process [72]. It is critical to understand how students manage the increased cognitive load when learning complex tasks [69]. Therefore, it is critical to consider these factors when designing effective learning experiences for students in various semesters or levels of education. Understanding the relationship between cognitive load, learning achievement, and semesters or levels in the context of mathematics learning enables educators to develop more effective strategies to support student learning and improve their academic outcomes.

## 3. The Research Methods

### 3.1. Types and Approaches

The purpose of this study was to determine the relationship between students' cognitive load and mathematics learning achievement, and the significance of differences in cognitive load for students across semester levels. The type of research is correlational and difference analysis using a quantitative approach [73].

### 3.2. Participants

Mathematics education students from the University of Muhammadiyah Malang comprised 79 (38.92%) of the total students, University of Muhammadiyah Surabaya 30 (34.88%) of the total students, and 49 (30.06%) of the total students at PGRI Jombang University in Indonesia who participated in the study. These respondents are suitable for survey research with a sample size of more than 30% [73, 74]. The selection of mathematics education students from three different universities provided a diverse sample that represented a wide range of educational environments in Indonesia. Cognitive load in learning is influenced by three dimensions: learner characteristics, instructional design, and environmental design [23, 44]. Students from semesters 3, 5, and 7 were chosen for this study based on their characteristics; there were 39, 38, and 81 students, respectively. The selection of students from Semesters 3, 5, and 7 was deliberate, taking into account their varying levels of academic experience and cognitive development. These semester levels enable an examination of how cognitive load evolves as students' progress through their academic journey, revealing how learner characteristics, such as academic maturity and subject matter familiarity, interact with cognitive load.

Furthermore, the heads of the three universities' mathematics education programs granted permission for this study. All participants voluntarily completed a Google form that inquired about their personal information, learning achievements in one of the mathematics courses, and their cognitive load in mathematics courses. In this study, learning achievement refers to the final grade received by participants in courses that correspond to the cognitive load questionnaire that they completed. Values are letters converted to numbers: A (4), B+ (3.5), B (3), C+ (2.5), C (2), D (1), and E (0). The identities of all the participants were kept confidential.

### 3.3. Instruments

This study used a cognitive load questionnaire with three items for intrinsic cognitive load (ICL), three for external cognitive load (ECL), and four for Germane cognitive load (GCL). Each item had a choice of confidence level of 0 to 10, where 0 stated that it never happened and 10 actually happened [24], [49], [75]. Table 1 lists the items from the cognitive-load questionnaire. The reliability of the cognitive-load instrument is presented in Table 2.

**Table 1. Cognitive load questionnaire (The authors' elaboration)**

| No. | Statements | Answer Scale |
|---|---|---|
| | | 0-1 9-10 |
| 1 | This course's topics are extremely complex. | |
| 2 | Learning this course includes formulas that I think are very complex. | |
| 3 | This course teaches concepts and definitions that I believe are extremely complex. | |
| 4 | The instructions and/or explanations provided during this course are very unclear. | |
| 5 | Instructions and/or explanations during this course are very ineffective. | |
| 6 | The language used in the course instructions and/or explanations is unclear. | |
| 7 | This course greatly improved my understanding of the topics covered. | |
| 8 | This course has greatly increased my knowledge and understanding of the course material. | |
| 9 | Learning this course improved my understanding of the material. | |
| 10 | This course greatly enhanced my understanding of concepts and definitions. | |

**Table 2. Reliability statistics (The authors' elaboration)**

| | McDonald's ω | Cronbach's α |
|---|---|---|
| ICL | 0.98 | 0.88 |
| ECL | 0.97 | 0.87 |
| GCL | 0.97 | 0.84 |
| Total | 0.97 | 0.84 |

The research procedure is presented in Figure 1.

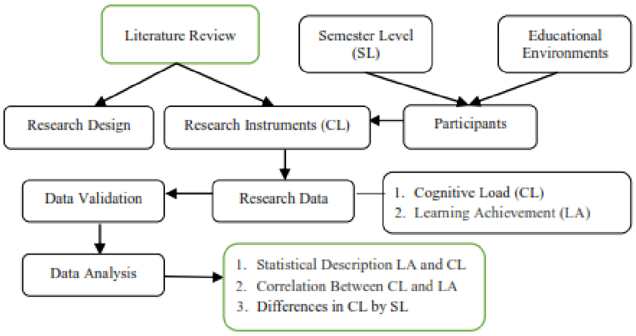


**Figure 1. The research procedures (The authors' elaboration)**

### 3.4. Data Analysis

Prior to analysis, the data were validated. Validation was carried out in two steps: identifying and evaluating outlier data that could jeopardize the analysis and determining instrument reliability. All the instruments were reliable and had no outliers. All variables were analyzed using descriptive statistics (mean and standard deviation) for achievement and cognitive load, and Pearson's correlation was used to test whether there was a significant relationship between students' achievement and cognitive load (ICL, ECL, GCL, and cognitive load total). One-way ANOVA was used to determine whether cognitive load was affected by the students' semester level. This test can be performed because the cognitive load data meets the requirements for homogeneity with the Test for Equality of Variances (Levene's), where the p-value is 0.41, greater than 0.05. All tests were performed using JASP 0.17.2.1, with a significance level of $p < 0.05$.

## 4. Results and Discussion

The study's findings and discussion are presented in accordance with the research objectives, describing cognitive load and learning achievement, the relationship between cognitive load and learning achievement, and the differences in cognitive load by semester level among mathematics education students.

### 4.1. Statistical Description of Learning Achievement and Cognitive Load

Table 3 presents the results of the statistical analysis of this variable.

Table 3 shows the difference in means between the three types of cognitive load: germane (GCL), External (ECL), and Intrinsic (ICL). The mean GCL was the largest, ECL was the smallest, and mean ICL was in the middle. These findings are consistent with previous research, which found that the mean German Cognitive Load (GCL) is the highest, exceeding the mean Intrinsic Cognitive Load (ICL), while the mean External Cognitive Load (ECL) is the lowest [25, 76, 77].

**Table 3. Descriptive statistics (The authors' elaboration)**

| | Achievement | Total ICL | Total ECL | Total GCL |
|---|---|---|---|---|
| Valid | 158 | 158 | 158 | 158 |
| Missing | 0 | 0 | 0 | 0 |
| Mean | 3.69 | 24.08 | 4.42 | 32.41 |
| Std. Deviation | 0.45 | 5.83 | 4.59 | 5.86 |
| Minimum | 2.00 | 0.00 | 0.00 | 11.00 |
| Maximum | 4.00 | 30.00 | 15.00 | 40.00 |

The highest mean germane cognitive load indicates that the cognitive load caused by factors relevant to a specific task or situation (e.g., task-related information) has a significant impact on student cognition. This could indicate that the students' primary focus was on processing information directly related to the task at hand. The lowest mean external cognitive load indicates that cognitive load derived from external factors around the student (for example, distractions from the surrounding environment) has a lower impact on students' cognition than cognitive load from other factors. The mean intrinsic cognitive load is between the mean ECL and GCL, indicating that the cognitive load resulting from the intrinsic complexity or difficulty of the task itself is between germane and external factors in terms of its impact on student cognition. This result also demonstrates that, despite the complexity of the mathematics course, the teacher's learning is extremely beneficial to students' cognition when compared to the cognitive load from other factors [78, 79].

In terms of learning achievement, these findings indicate that focusing on GCL or cognitive load directly related to the learning task has a significant impact on learning achievement [23, 51]. ICL factors, such as the intrinsic complexity of the learning material itself, are important for learning achievement and must be considered. A thorough understanding of ICL factors and their management can enhance learning effectiveness and achievement [26, 76]. Although external cognitive load may have a smaller impact than other types of cognitive load, educators should consider and reduce external distractions in the learning environment. Educators can help students maximize their cognitive resources, increase their focus, and improve their learning outcomes by creating a conducive learning environment, reducing noise levels, and designing clear and organized teaching materials. Ignoring external cognitive loads can reduce learning performance and jeopardize students' overall academic success [80, 81]. Studies have also found that the use of technologies such as Augmented Reality (AR) can influence students' cognitive load profiles, self-efficacy, and behavioral patterns in science learning. [82].

This concept has important implications for cognitive development in various contexts, including instructional design. When developing strategies to improve cognitive performance, emphasis on germane cognitive load may become more important. The discovery that germane cognitive load has a significant impact on learning performance emphasizes the importance of developing learning strategies that reduce unnecessary cognitive load and focus on the material at hand. Understanding how cognitive factors influence learning outcomes can help teachers and curriculum designers to create more effective learning strategies. Further research in this area is expected to provide a better understanding of how to optimize the learning process by addressing complex cognitive factors.

### 4.2. Correlation between Cognitive Load and Learning Achievement

Before examining the relationship between learning achievement and cognitive load, we performed a data normality test. The Shapiro-Wilk test was used to determine multivariate normality. Table 4 shows that the data were normally distributed with a p-value of < 0.05. Pearson's correlation was used to assess the significance of the relationship between learning achievement and cognitive load, as shown in Table 5.

**Table 4. Shapiro-Wilk test for multivariate normality (The authors' elaboration)**

| Shapiro-Wilk | p |
|---|---|
| 0.81 | < 0.001 |

**Table 5. Pearson's correlations (The authors' elaboration)**

| Variable | | Achievement | ICL | ECL | GCL | Total |
|---|---|---|---|---|---|---|
| 1. Achievement | Pearson's r | — | | | | |
| | p-value | — | | | | |
| 2. ICL | Pearson's r | -0.04 | — | | | |
| | p-value | 0.62 | — | | | |
| 3. ECL | Pearson's r | -0.12 | -0.24 | — | | |
| | p-value | 0.13 | 0.00 | — | | |
| 4. GCL | Pearson's r | 0.20 | 0.64 | -0.58 | — | |
| | p-value | 0.01 | < 0.001 | < 0.001 | — | |
| 5. Total | Pearson's r | 0.04 | 0.90 | -0.02 | 0.73 | — |
| | p-value | 0.63 | < 0.001 | 0.83 | < 0.001 | — |

Based on the results in Table 5, the Pearson r value is negative, and the p-value = 0.62 (0.13) > 0.05, indicating that there is a negative and insignificant relationship or effect between learning achievement and intrinsic and extraneous cognitive load, which is consistent with previous studies that have found a negative relationship between learning achievement and extraneous cognitive load [51, 83]. In contrast to the findings of previous studies, which state that academic achievement correlates with cognitive load and includes both intrinsic and extraneous components [23, 51, 84]. These findings suggest that students' learning achievements deteriorate as their intrinsic and external cognitive loads increase. However, this relationship was not statistically significant enough to be considered statistically strong. Extraneous cognitive load, which includes information unrelated to a task, has been shown to reduce learning effectiveness [51, 85]. As a result, reducing the extraneous cognitive load is critical for optimizing cognitive resources during the learning process. [86]. Furthermore, the impact of extraneous loads on attention in learning suggests that distractions should be addressed to improve learning outcomes. These findings highlight the negative effects of excessive extraneous cognitive load on learning performance and emphasize the importance of reducing such cognitive load to improve learning outcomes. These findings imply that while there is a tendency for intrinsic and external cognitive load to be negatively correlated with learning achievement, the relationship is not statistically significant. This suggests that other factors may be important in determining students' learning achievements.

Furthermore, from Table 5, it is also obtained that Pearson's r value = 0.20 and p value = 0.01 < 0.05 which means that germane cognitive load has a significant positive effect on learning achievement, although very small, which is in line with the results of research that states that germane cognitive load has a significant positive effect on learning achievement, although very small [51, 58, 83, 87]. This suggests that students' learning achievement improved as their germane cognitive load increased. Although the effect was small, the presence of a significant relationship between germane cognitive load and learning achievement suggests that task-relevant factors play an important role in improving learning achievement.

Germane cognitive load is critical for the development of students' cognitive frameworks and academic success [51, 88]. Educators must prioritize germane cognitive load because of its close relationship with educational achievement [85, 89]. Recognizing and distinguishing between intrinsic, extraneous, and germane cognitive loads is critical for developing effective teaching strategies and improving learning environments [26, 32, 76]. Academic performance can be improved by reducing extraneous cognitive load while increasing germane cognitive load by using appropriate instructional design and learning approaches [58]. The relevance of cognitive load, while having a slight impact on academic achievement, is crucial because of its close connection with learning processes. Through the efficient management of cognitive load and promotion of relevant cognitive processing, educators can improve learning results and support students in attaining academic excellence.

Overall, cognitive load had a small and insignificant positive impact on student achievement in mathematics education. This suggests that in the context of your study, cognitive load does not have a significant impact on student achievement. Although there was a small positive effect, it was not statistically significant enough to be considered significant on learning achievement. Cognitive load and student performance in mathematics education have a complex relationship. Although the cognitive load theory asserts that managing cognitive load is required for learning, its impact on academic achievement varies. The cognitive load during problem-solving was studied to determine how it affects the learning process. Instead, they emphasized the significance of cognitive and non-cognitive factors in mathematics achievement, such as mathematics anxiety and student-teacher relationships, implying that cognitive load may not have a significant impact on student performance [90]. Furthermore, the relationship between homework time and academic achievement varied by country, suggesting that cognitive load does not always correlate with academic success [91]. This finding suggests that, when developing learning strategies for mathematics education students, cognitive load factors may not be the primary focus. Other factors such as teaching methods, curriculum, and student motivation may have a greater influence on learning outcomes.

### 4.3. Differences in Cognitive Load by Semester Level

Before examining the difference in cognitive load based on semester level, a data homogeneity test was performed. Levene's test was used to determine the data homogeneity. Table 6 shows that the data are homogeneous, with a p-value = 0.41 of 0.05. Furthermore, one-way ANOVA was used to assess the difference in the cognitive load based on semester level, as shown in Table 7, and continued with Tukey's post hoc comparisons, which are shown in Table 8.

**Table 6. Test for equality of variances (Levene's) (The authors' elaboration)**

| F | df1 | df2 | p |
|---|---|---|---|
| 0.90 | 2.00 | 155.00 | 0.41 |

**Table 7. ANOVA – total CL (The authors' elaboration)**

| Cases | Sum of Squares | df | Mean Square | F | p |
|---|---|---|---|---|---|
| Semester level | 14.46 | 2 | 7.23 | 0.08 | 0.92 |
| Residuals | 14038.30 | 155 | 90.57 | | |

*Note:* Type III Sum of Squares

**Table 8. Post-hoc comparisons: semester level (The authors' elaboration)**

| Semester level | | Mean Difference | SE | t | $p_{tukey}$ |
|---|---|---|---|---|---|
| 3 | 5 | -0.83 | 2.17 | -0.38 | 0.92 |
| | 7 | -0.59 | 1.85 | -0.32 | 0.95 |
| 5 | 7 | 0.24 | 1.87 | 0.13 | 0.99 |

*Note:* P-value adjusted for comparing a family of 3

The phrase "p-value adjusted for comparing a family of 3" means that the p-value has been adjusted to account for the fact that you are performing three simultaneous comparisons of the means in an ANOVA test. This adjustment ensured that the findings were statistically significant and not the result of chance.

According to the results shown in Tables 7 and 8, there was no significant difference in the cognitive load among mathematics education students in semesters 3, 5, and 7. This suggests that semester level has no significant effect on the level of cognitive load experienced by students. This suggests that students' academic progress in later semesters is not directly related to changes in their cognitive load. Several studies that have investigated factors affecting cognitive load prove that variations in the cognitive load experience of students involved in Augmented Reality (AR)-assisted science learning (AR) [82], comprehension and information retrieval tasks, especially when using mobile devices [92], questioning activities to reduce cognitive load [34], the influence of element interactivity, the effect of practice, and individual differences in cognitive load during algebraic problem solving [45], and the significance of intrinsic, extraneous, and germane cognitive loads in learning efficacy [51]. These findings suggest that the semester level may not be the only factor influencing college students' cognitive load. Instead, the nature of the task and learning environment, such as augmented reality and online activities as well as instructional methods, may have a greater impact on students' cognitive load. This finding implies that students' semester levels should not be considered specifically when planning learning strategies and managing cognitive load. Other factors, such as task complexity and the characteristics of learning materials, may be more important when creating effective learning experiences.

## 5. Conclusion

This study provides critical insights into the role of cognitive load in shaping learning achievement in mathematics education at the university level. The primary findings show that intrinsic and extraneous cognitive load are negatively related to students' learning outcomes, whereas germane cognitive load is positively related, implying that students perform better when their cognitive resources are better aligned with learning tasks. Furthermore, the study found that semester level had no significant effect on the cognitive load experienced by students, emphasizing that cognitive load dynamics remain consistent across different stages of academic progression.

The findings of this study' are consistent with previous research that emphasizes the importance of managing cognitive load to improve learning outcomes. Similar to Sweller's Cognitive Load Theory, which emphasizes the negative effects of excessive intrinsic and extraneous loads, this study supports the idea that germane cognitive load is beneficial for deeper learning. However, unlike some studies that suggest a strong link between cognitive load and academic performance, our findings show that this relationship is more complex and inconsistent, particularly in mathematics education.

This study's findings have important implications for math educators and curriculum developers. Understanding that cognitive load is not always directly related to academic achievement implies that instructional strategies should focus on optimizing the types of cognitive load that students face. Educators can create more effective learning environments that promote better understanding and retention of mathematical concepts by reducing extraneous and increasing germane loads.

Considering the study's limitations, future research should aim to build on these findings using larger and more diverse samples to improve generalizability. Furthermore, investigating the effects of additional variables such as psychological and social factors, as well as the role of technology in the learning process, may provide a more complete picture of how cognitive load influences academic performance. Future studies should use longitudinal designs to track changes in cognitive load and their impact on learning over time and across educational contexts. Such research could help develop more tailored educational strategies that address students' cognitive needs in math and other disciplines.

## Declarations

*Author Contributions*

Conceptualization, B. and I.S.; methodology, B. and S.I.; software, W.S.H.; validation, B., S.I. and W.S.H.; formal analysis, B.; investigation, I.H. and S.I.; resources, B.; data curation, B.; writing—original draft preparation, W.S.H.; writing—review and editing, B.; visualization, I.S.; supervision, B.; project administration, B.; funding acquisition, B. All authors have read and agreed to the published version of the manuscript.

*Data Availability Statement*

The data presented in this study are available on request from the corresponding author.

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*Institutional Review Board Statement*

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of the University of Muhammadiyah Malang, University of Muhammadiyah Surabaya, and University of PGRI Jombang.

*Informed Consent Statement*

Informed consent was obtained from all subjects involved in the study.

*Conflicts of Interest*

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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