Volume 3 Number 2 (2025)
July – December 2025
Page: 87-94

ISSN: 3031-2884
EDUJAVARE PUBLISHING
https://edujavare.com/index.php/edujavare

The Effect of Segmenting and Contiguity Principles on Students' Cognitive Load in Science Learning

Aisyah Ary Yatma[1], Ismail Fikri Natadiwijaya[2], Putri Anjarsari[3]
[1,2,3] Universitas Negeri Yogyakarta, Indonesia
Correspondent email: aisyahary.2022@student.uny.ac.id

Article history Submitted: 2025/10/11; Revised: 2025/11/15; Accepted: 2025/12/04

Abstract

Science learning requires students to understand concepts deeply; however, the complexity of the material and the dense and poorly structured presentation of information often increase students' cognitive load. This study aims to examine the effect of segmenting and contiguity principles on students' cognitive load in science learning. A quasi-experimental method with a posttest-only control group design was employed. The participants were eighth-grade students of MTs Negeri 9 Bantul, divided into an experimental group and a control group. The experimental group was taught using learning activities based on segmenting and contiguity principles, while the control group received regular instruction. Students' cognitive load, particularly intrinsic and extraneous cognitive load, was measured using the Paas Mental Effort Rating Scale. The data were analyzed using descriptive statistics, independent samples t-test, and effect size. The results revealed that the application of segmenting and contiguity principles had a significant and moderate effect on reducing students' cognitive load compared to conventional science learning ($p = 0.016$; Cohen's $d = 0.633$). These findings indicate that instructional designs applying segmenting and contiguity principles are effective in managing students' cognitive load and supporting more meaningful and cognitively efficient science learning

Keywords contiguity principle; cognitive load; multimedia learning, science learning; segmenting principle.

INTRODUCTION

Science learning plays a strategic role in equipping students with scientific knowledge, skills, and attitudes necessary to understand natural phenomena and everyday life (Hasasiyah dkk., 2020). Ideally, science learning should not only emphasize content mastery but also foster critical thinking, problem-solving, and the ability to relate concepts to real-life contexts (Pebriani dkk., 2022). However, empirical evidence indicates that students' understanding of science remains suboptimal. A study by Ainul dkk., (2025) reported that the average science comprehension score of junior high school students reached only 46.67, with 43.33% categorized at a low level, reflecting a gap between instructional goals and actual learning outcomes.

One major factor contributing to this condition is the complexity and abstract nature of science content, particularly in biology topics such as the human circulatory system, which require high levels of visualization and reasoning. Learning difficulties become particularly apparent in topics involving complex biological systems, such as the human circulatory system, which includes anatomical structures and physiological processes that are difficult for students to conceptualize (Dita dkk., 2023). Previous classroom observations and studies also show that many students rely on rote memorization and struggle when faced with tasks requiring conceptual understanding (Yamah, 2022). These conditions indicate limitations in students' ability to process and integrate scientific information meaningfully.

From a cognitive perspective, such learning difficulties are closely related to cognitive load. Cognitive Load Theory (CLT) explains that learning is constrained by the limited capacity of working memory, and excessive information or poorly designed instructional materials may overwhelm learners' cognitive resources (Paas & Ayres, 2014; Sweller dkk., 2019). When instructional designs fail to align with human cognitive architecture, students may experience high cognitive load, resulting in difficulties in understanding, problem-solving, and knowledge retention (Yohanes & Lusbiantoro, 2019). Moreover, complex learning environments that require deep cognitive processing may further increase mental effort if not supported by appropriate instructional design (Haq & Prasetiyo, 2025; Maulidya dkk., 2025). To address this issue, instructional design principles that support effective information processing are essential. Among these, the segmenting and contiguity principles have been widely recognized in multimedia learning research. The segmenting principle emphasizes presenting learning materials in smaller, meaningful units to match learners' cognitive capacity, while the contiguity principle stresses the importance of presenting related verbal and visual information close together in time and space (Mayer, 2020; Mayer & Pilegard, 2014). These principles are closely related to the chunking strategy, which involves organizing information into manageable units to reduce working memory load and enhance learning efficiency (Harmiardillah dkk., 2025).

Empirical studies have demonstrated the effectiveness of these principles in reducing cognitive load and improving learning outcomes. Kruger and Doherty (2016) found that segmented instructional videos reduced students' mental effort and improved comprehension. Similarly, Biard dkk., (2018) reported better learning performance among students who learned from segmented materials compared to continuous presentations. In terms of contiguity, Schneider dkk. (2021) showed that spatial contiguity improved processing efficiency and reduced extraneous cognitive load, while Ge dkk. (2022) emphasized the importance of temporal contiguity in enhancing retention and students' attitudes toward learning materials. In classroom contexts, these principles are particularly relevant for supporting students in processing complex scientific concepts without overloading their working memory.

Despite these promising findings, the implementation of segmenting and contiguity principles in secondary school science learning remains limited. Studies on instructional media development indicate that many learning materials are still characterized by split attention, redundancy, and incoherence, which potentially increase students' cognitive load (Azka &

Surjono, 2025; Idrus, 2023). This suggests a gap between theoretical recommendations and actual classroom practices.

Therefore, this study aims to investigate the effect of segmenting and contiguity principles on students' cognitive load in science learning, particularly in learning the human circulatory system at the junior high school level. Specifically, this study examines whether the application of these principles significantly reduces students' intrinsic and extraneous cognitive load compared to conventional instructional practices

METHODS

This study employed a quantitative approach using a quasi-experimental design with a posttest-only control group. The participants were eighth-grade students of MTs Negeri 9 Bantul, Yogyakarta, Indonesia, selected through purposive sampling. From five available classes, two classes with relatively equivalent academic characteristics, based on previous academic records and teacher recommendations, were chosen: class VIII D (30 students) as the experimental group and class VIII C (31 students) as the control group. The experimental group received science instruction designed using segmenting and contiguity principles, in which learning materials were presented in smaller, meaningful segments with close integration of verbal and visual information. Specifically, learning materials were divided into sequential subtopics, and visual representations were presented simultaneously with corresponding verbal explanations to avoid split attention. The control group was taught using conventional scientific instruction without explicit application of these principles. The treatment was implemented during science learning on the topic of the human circulatory system. Students' cognitive load was measured using a questionnaire adapted from the Paas Mental Effort Rating Scale (Paas, 1992), consisting of 24 items covering intrinsic and extraneous cognitive load, rated on a 9-point mental effort rating scale. The cognitive load questionnaire was adapted from the Paas Mental Effort Rating Scale and expanded to capture students' intrinsic and extraneous cognitive load. The adaptation was intended to provide a more detailed measurement of students' cognitive experiences during learning. Content validity was examined through expert judgment by specialists in science education and educational psychology. The reliability of the instrument was confirmed using Cronbach's alpha, indicating acceptable internal consistency. Data were analyzed using descriptive statistics and an independent samples t-test, with effect size calculated to determine the magnitude of the treatment effect

FINDINGS AND DISCUSSION

Results

Students' cognitive load was measured after the learning sessions using a 24-item questionnaire consisting of intrinsic and extraneous cognitive load indicators. Higher scores indicate higher levels of perceived cognitive load. Table 1 presents the descriptive statistics of students' cognitive load in both groups.

Table 1. Descriptive Statistics of Students' Cognitive Load

Group	Mean	SD	Min	Max
Experimental 0	88.27	27.86	31	142
Control 1	107.10	31.50	48	185

The results indicate that the experimental group experienced a lower level of cognitive load (M = 88.27) compared to the control group (M = 107.10). The control group also showed greater variability, as indicated by its higher standard deviation. This indicates that students in the experimental group experienced lower mental effort during learning compared to those in the control group. These findings suggest that learning designed using segmenting and contiguity principles tends to reduce students' cognitive load compared to conventional scientific instruction.

Further analysis was conducted by separating cognitive load into intrinsic and extraneous components. The percentage values represent the proportion of the obtained score relative to the maximum possible score for each cognitive load indicator.The mean scores and percentages of each indicator are presented in Table 2.

Table 2. Percentage Distribution of Intrinsic and Extraneous Cognitive Load

Indicator	**Experimental**	**Control**
Intrinsic Cognitive Load	41.18%	50.60%
Extraneous Cognitive Load	40.56%	48.57%

The experimental group showed lower intrinsic and extraneous cognitive load than the control group. This indicates that segmenting and contiguity principles not only helped reduce the complexity experienced by students in understanding the material but also minimized unnecessary cognitive burden caused by instructional presentation.

To examine whether the difference in cognitive load between groups was statistically significant, an independent samples t-test was conducted. The independent samples t-test revealed a statistically significant difference between the experimental and control groups ($p = 0.016 < 0.05$), indicating that the learning design based on segmenting and contiguity principles significantly affected students' cognitive load. Preliminary assumption testing indicated that the data met the requirements for parametric analysis.

Furthermore, the effect size analysis yielded a Cohen's d value of 0.633, which is categorized as a medium effect. This result suggests that the application of segmenting and contiguity principles had a moderate and meaningful impact on reducing students' cognitive load in science learning.

Discussion

The findings of this study indicate that instructional designs based on segmenting and contiguity principles can effectively reduce students' cognitive load in science learning contexts. Students who learned through instructional materials designed according to these principles experienced lower overall cognitive load compared to those who received conventional instruction. This result highlights the importance of instructional design in supporting students' cognitive processes when learning complex scientific content.

From the perspective of CLT, cognitive load emerges due to the limited capacity of working memory when processing complex or poorly organized information (Sweller, 2019). In this study, the lower cognitive load observed in the experimental group suggests that the learning design successfully managed students' cognitive resources by aligning instructional presentation with the limited capacity of working memory. When learning materials are presented in smaller, meaningful segments, students are better able to process information sequentially without being overwhelmed by excessive cognitive demands. This supports Sweller's assertion that well-structured instructional designs can optimize the use of working memory resources and facilitate more efficient learning.

The reduction in both intrinsic and extraneous cognitive load further strengthens this interpretation. The lower intrinsic cognitive load observed in the experimental group suggests that segmenting the content helped students manage the inherent complexity of the human circulatory system, rather than eliminating the complexity itself. By organizing information into manageable subtopics, students were able to focus on understanding relationships among concepts without experiencing excessive cognitive strain. This finding is consistent with Sweller et al. (2023), who emphasize that well-organized instructional design can regulate element interactivity and make complex material more manageable for learners.

Meanwhile, the decrease in extraneous cognitive load indicates the effectiveness of the contiguity principle in minimizing unnecessary cognitive processing. Presenting verbal explanations in close spatial and temporal proximity to relevant visual representations reduced split attention and helped students integrate information more efficiently. This finding aligns with multimedia learning theory, which posits that learners process information more effectively when related verbal and visual elements are presented together rather than separately (Mayer & Moreno, 2003; Mayer, 2009).

The effectiveness of these principles becomes more apparent when segmenting and contiguity principles are used to facilitate deep learning processes. Deep learning emphasizes conceptual understanding, reflection, and meaningful knowledge construction rather than surface memorization (Weng et al., 2023; Suwandi et al., 2024). When learning activities are structured into manageable segments and presented coherently, students are better able to allocate their cognitive resources toward understanding relationships among concepts rather than merely coping with information overload.

The moderate effect size obtained in this study (Cohen's d = 0.633) indicates that the impact of the intervention was meaningful yet realistic in authentic classroom conditions. As cognitive load is influenced by multiple internal and external factors—such as students' prior knowledge, working memory capacity, and learning strategies—interventions based on instructional design typically produce gradual improvements rather than extreme changes (Sweller et al., 2019). Thus, the observed effect reflects a consistent and pedagogically valuable contribution to improving learning efficiency.

These findings are consistent with prior studies demonstrating that instructional principles grounded in CLT and multimedia learning theory can effectively reduce students' cognitive load and enhance learning quality. Similar to how chunking techniques in memory training help optimize cognitive processing by organizing information into meaningful units, segmenting in instructional design serves to regulate the flow and complexity of information, allowing students to engage more deeply with learning materials.

From a pedagogical perspective, this study suggests that science teachers should pay close attention not only to the content being taught but also to how that content is structured and presented. Teachers are therefore encouraged to intentionally design instructional materials by segmenting complex content and ensuring close integration between visual and verbal information, in order to support students' cognitive processes and promote more meaningful science learning.

CONCLUSION

This study demonstrates that the application of segmenting and contiguity principles has a significant effect on reducing students' cognitive load in science learning. Students who learned through instructional designs based on these principles experienced lower overall cognitive load compared to those who received conventional instruction. This finding indicates that how learning materials are structured and presented plays a crucial role in managing students' mental effort during the learning process.The results further show that both intrinsic and extraneous cognitive load were lower in the experimental group. Segmenting helped students manage the inherent complexity of the human circulatory system by organizing content into meaningful units, while contiguity minimized unnecessary cognitive processing by reducing split attention between verbal and visual information. These findings support the core assumptions of Cognitive Load Theory and multimedia learning principles, which emphasize the importance of aligning instructional design with learners' cognitive architecture. Moreover, the moderate effect size suggests that the intervention provided a meaningful and realistic contribution to improving learning efficiency in authentic classroom contexts. Rather than producing extreme changes, the application of segmenting and contiguity principles supported more efficient cognitive processing and facilitated deep learning processes, particularly conceptual understanding and knowledge integration. Based on these findings, integrating segmenting and contiguity principles into science instruction can be recommended as a practical strategy for designing cognitively efficient learning environments. Future research may explore the long-term effects of these principles on learning retention and transfer, as well as their implementation in different science topics and educational levels.

REFERENCES

Ainul, S. A. S., Wakhidah, N., Arum, W. F., Hidayati, S., & Indayati, T. (2025). Analisis Tingkat Pemahaman Konsep Siswa Pada Pembelajaran IPA: Analysis of Students' Concept Understanding Level in Science Learning. Edu-Sains: Jurnal Pendidikan Matematika dan Ilmu Pengetahuan Alam, 14(1), 7–15. https://doi.org/10.22437/jmpmipa.v14i1.39419

Azka, R., & Surjono, H. D. (2025). Analisis multimedia instruksional modul ajar matematika kelas VII SMP Terbuka ditinjau dari cognitive load. Pythagoras: Jurnal Program Studi Pendidikan Matematika, 14(1), Article 1. https://doi.org/10.33373/pyth.v14i1.6901

Biard, N., Cojean, S., & Jamet, E. (2018). Effects of segmentation and pacing on procedural learning by video. Computers in Human Behavior, 89, 411–417. https://doi.org/10.1016/j.chb.2017.12.002

Dita, K. I., Tuririday, H. T., Damopolii, I., & Latjompoh, M. (2023). Designing the human circulatory system e-module to increase student achievement. Inornatus: Biology Education Journal, 3(2), 75–84. https://doi.org/10.30862/inornatus.v3i2.422

Ge, S., Hai Leng, C., & Baharudin, S. M. (2022). The effect of multimedia and temporal contiguity principles on students' attitude and retention in learning Japanese language. International Journal of Chinese Education, 11(2), 2212585X221099964. 10.1177/2212585X221099964

Haq, M. D., & Prasetiyo, N. T. (2025). Deep learning sebagai pendekatan transformasional dalam pendidikan: Sebuah tinjauan literatur. Jurnal Studi Guru Dan Pembelajaran, 8(3), 1826–1842. https://doi.org/10.30605/jsgp.8.3.2025.7021

Harmiardillah, S., Kusbiantoro, D., & Safitri, D. I. A. (2025). Improving Short-Term Memory of School-Age Children through Brain Gym with the Chunking Technique Mnemonic Approach. Pijar : Jurnal Penelitian Bidang Pendidikan Dan Pembelajaran, 5(1), 1–10. https://doi.org/10.56393/pijar.v5i1.2836

Hasasiyah, S. H., Hutomo, B. A., Subali, B., & Marwoto, P. (2020). Analisis Kemampuan Literasi Sains Siswa SMP pada Materi Sirkulasi Darah. Jurnal Penelitian Pendidikan IPA, 6(1), Article 1. 10.29303/jppipa.v6i1.193

Idrus, I. (2023). Pembelajaran Berbasis Kognitif Multimedia Pada Kalbu Perspektif Al-Qur'an [Masters, Institut PTIQ Jakarta]. https://repository.ptiq.ac.id/id/eprint/1321/ https://doi.org/10.53038/alashriyyah.v9i2.171

Maulidya, D., Setiawati, D. N. A. E., Umamy, N. A., & Syukri, M. (2025). Analisis Literatur Peran Deep Learning dalam Mendorong Pembelajaran Bermakna di Sekolah Dasar: Penelitian. Jurnal Pengabdian Masyarakat Dan Riset Pendidikan, 4(2), 9072–9084. https://doi.org/10.31004/jerkin.v4i2.3330

Mayer, R. E. (2020). Multimedia Learning (3 ed.). Cambridge University Press; Cambridge Core. https://doi.org/10.1017/9781316941355

Mayer, R. E., & Pilegard, C. (2014). Principles for managing essential processing in multimedia learning: Segmenting, pre-training, and modality principles. https://doi.org/10.1017/CBO9781139547369.01

Paas, F., & Ayres, P. (2014). Cognitive Load Theory: A Broader View on the Role of Memory in Learning and Education. Educational Psychology Review, 26(2), 191–195. https://doi.org/10.1007/s10648-014-9263-5

Pebriani, N. P. I., Putrayasa, I. B., & Margunayasa, I. G. (2022). Pengembangan E-LKPD berbasis HOTS (Higher Order Thinking Skill) dengan pendekatan saintifik pada pembelajaran IPA tema 8 kelas V SD. Jurnal Penelitian Dan Evaluasi Pendidikan Indonesia, 12(1), 76–89. https://doi.org/10.23887/jpepi.v12i1.980

Schneider, S., Krieglstein, F., Beege, M., & Rey, G. D. (2021). How organization highlighting through signaling, spatial contiguity and segmenting can influence learning with concept maps. Computers and Education Open, 2, 100040. https://doi.org/10.1016/j.caeo.2021.100040

Sweller, J., Van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive Architecture and Instructional Design: 20 Years Later. Educational Psychology Review, 31(2), 261–292. https://doi.org/10.1007/s10648-019-09465-5

Yamah, Y. (2022). Upaya Meningkatkan Prestasi Belajar IPA tentang Sistem Peredaran Darah Manusia melalui Creative Problems Solving pada Siswa Kelas VIII-G Semester 1 SMP Negeri 1 Karangrejo Tulungagung Tahun Pelajaran 2018/2019. Jurnal Pembelajaran dan Ilmu Pendidikan, 2(3), 273–278. https://doi.org/10.28926/jpip.v2i3.473

Yohanes, B., & Lusbiantoro, R. (2019). Teori Beban Kognitif: Elemen Interaktivitas Dalam Pembelajaran Matematika. INSPIRAMATIKA, 5(1), 1–8. https://doi.org/10.52166/inspiramatika.v5i1.1477 https://doi.org/10.52166/inspiramatika.v5i1.1477

.