The Application of Cognitive Ergonomics in Improving Observation Skills and Curiosity in Elementary Schools

Sumianto[1], Yusuf Hanafi[2], Toto Nusantara[3], Mardhatillah[4], Adi Atmoko[5], Musnar Indra Daulay[6], Yenni Fitra Surya[7]
Elementary School Teacher Education Study Program, Faculty of Teacher Training and Education, Universitas Pahlawan Tuanku Tambusai, Indonesia[1]
Department of Arabic, Faculty of Letters, Universitas Negeri Malang, Indonesia[2]
Mathematics Education Study Program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia[3]
Elementary Education, Postgraduate, Universitas Negeri Malang, Indonesia[4]
Guidance and Counseling Study Program, Faculty of Education, Universitas Negeri Malang, Indonesia[5]
Early Childhood Teacher Education Study Program, Faculty of Teacher Training and Education, Universitas Pahlawan Tuanku Tambusai, Indonesia[6]
Department of Elementary Teacher Education, Faculty of Teacher Training and Education, Universitas Pahlawan Tuanku Tambusai, Indonesia[7]
E-mail: sumianto@universitaspahlawan.ac.id[1], yusuf.hanafi.fs@um.ac.id[2], toto.nusantara.fmipa@um.ac.id[3], Mardhatillah.pasca@um.ac.id[4], adi.atmoko.fip@um.ac.id[5], musnarindradaulay@gmail.com[6],Yenni.fitra13@gmail.com[7]
Correspondent Author: Sumianto, sumianto@universitaspahlawan.ac.id
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Abstrack

Observation skills and curiosity are crucial for elementary students' learning, but remain underdeveloped in Indonesia, where PISA (2021) reported that 56% of students struggle to identify key information in texts. This quasi-experimental study involved 80 fourth-grade students, divided into two groups: experimental and control. Over four weeks, the experimental group received lessons that integrated Dual Coding (text-image pairing and color-coded diagrams) and Chunking (breaking content into small, thematic units)—a 25-item, validated test measured both skills. Results from independent t-tests showed significant improvements ($p < 0.05$) across all indicators, with an average score increase of 18% in the experimental group. These findings confirm that structured multimodal strategies enhance visual-verbal processing, analytical thinking, and exploratory motivation. Practically, the study suggests that primary school curricula should incorporate cognitively ergonomic techniques to foster deeper engagement and higher-order thinking, offering a replicable model for inclusive and practical instructional design.
Keywords: cognitive ergonomics, dual coding, chunking, observation skills, curiosity

Abstrak

Keterampilan pengamatan dan rasa ingin tahu sangat penting bagi proses belajar siswa sekolah dasar, namun masih kurang berkembang di Indonesia. Menurut laporan PISA (2021), 56% siswa kesulitan mengidentifikasi informasi penting dalam teks. Studi quasi-eksperimental ini melibatkan 80 siswa kelas empat, dibagi menjadi kelompok eksperimen dan kontrol. Selama empat minggu, kelompok eksperimen menerima pelajaran yang mengintegrasikan Dual Coding (pemasangan teks dan gambar, diagram berwarna) dan Chunking (membagi konten menjadi unit-unit kecil dan tematik). Sebuah tes validasi berisikan 25 item mengukur kedua keterampilan tersebut. Hasil uji t independen menunjukkan peningkatan signifikan ($p < 0.05$) pada semua indikator, dengan peningkatan rata-rata skor sebesar 18% pada kelompok eksperimen. Temuan ini membuktikan bahwa strategi multimodal terstruktur meningkatkan pemrosesan visual-verbal, pemikiran analitis, dan motivasi eksploratif. Secara praktis, studi ini menyarankan agar kurikulum sekolah dasar mengintegrasikan teknik kognitif ergonomis untuk mendorong keterlibatan yang lebih dalam dan pemikiran tingkat tinggi, menawarkan model yang dapat direplikasi untuk desain instruksional yang inklusif dan efektif.
***Keywords**: ergonomi kognitif, dual coding, chunking, keterampilan pengamatan, rasa ingin tahu*

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INTRODUCTION

Basic education plays a crucial role in shaping children's cognitive skills and influencing their academic development at higher levels (Meder et al., 2021). Children are in a stage of rapid cognitive development at this age, and engaging in appropriate learning can have a lasting impact on their intellectual progress. One crucial aspect that needs to be developed in children at the elementary school level is observation skills and curiosity (Hartikainen et al., 2021). These skills influence children's ability to gather information from their surroundings and play a role in developing the critical thinking patterns necessary to understand and solve problems (Murayama, 2022). In Indonesia, teaching practices in primary schools remain dominated by conventional lecture-based approaches that prioritize verbal instruction. Such methods often fail to engage digital native learners, who are accustomed to visually rich and interactive environments. This mismatch can hinder the development of essential skills, such as observation and curiosity, which are vital for critical and creative thinking in the 21st century. Therefore, innovative approaches to learning are necessary to optimize students' cognitive potential, one of which is the application of cognitive ergonomics principles (Aldridge & Bianchet, 2022).

Cognitive ergonomics, which focuses on how human mental processes can be influenced by system design, has shown great potential in enhancing learning processes (Yu et al., 2022). A critical concept in cognitive ergonomics is Dual Coding, which suggests combining verbal and visual representations to convey information, thereby improving understanding and memory (Grabau, 2022). Another principle is Chunking, which divides complex information into smaller, more manageable pieces for human memory (Christensen & Bicknell, 2022). However, despite applying these principles across various disciplines, their use in elementary education, particularly for developing observation skills and curiosity in children, remains limited (Nikou, 2024). Ergonomi kognitif menawarkan alternatif yang menjanjikan dengan menyelaraskan desain instruksional dengan proses kognitif manusia. Dua prinsip utama—Dual Coding, yang menggabungkan informasi visual dan verbal untuk meningkatkan pemahaman dan retensi, dan Chunking, yang membagi materi kompleks menjadi unit-unit yang dapat dikelola—berdasarkan teori beban kognitif dan didukung oleh teori tahap operasional konkret Piaget, yang menekankan ketergantungan anak-anak pada representasi konkret dan visual untuk memahami konsep abstrak. Therefore, this study focuses on testing the application of the Dual Coding and Chunking principles in improving elementary school students' observation skills and curiosity.

Although cognitive ergonomics theories have been applied in various disciplines, their specific application in the context of elementary education is still limited. Primary education often relies on conventional learning methods that do not fully utilize students' cognitive potential, especially in developing observation skills and curiosity (Rubtsov & Ulanovskaya, 2020). For example, students in many elementary schools are still more involved in traditional, verbal teaching-centered learning methods without utilizing multimodal approaches that can significantly enhance their understanding. This results in their inability to observe phenomena around them and limits their curiosity to explore topics they have not yet learned (Ruiz-Martín & Bybee, 2022).

This study investigates whether applying cognitive ergonomics principles. Specifically, Dual Coding and Chunking can address this issue by improving students' observation skills and strengthening their curiosity. Thus, this study attempts to answer several key questions: (1) What is the effect of applying cognitive ergonomics principles,

specifically Dual Coding and Chunking, on students' observation skills in elementary school? (2) How can applying Dual Coding and Chunking enhance elementary school students' curiosity? (3) Are there significant differences between the group that applied cognitive ergonomics principles and those that used conventional learning methods regarding observation skills and curiosity? The main objective of this study is to explore and test the effect of applying cognitive ergonomics principles (Dual Coding and Chunking) in improving elementary school students' observation skills and curiosity. Specifically, this study aims to determine whether the application of Dual Coding and Chunking techniques can improve the observational skills of elementary school students. To analyze how applying these techniques can strengthen students' curiosity in learning. To assess the differences between groups that use cognitive ergonomics principles and control groups regarding observation skills and curiosity.

The urgency of this research lies in the fact that basic education plays a central role in shaping students' character and cognitive skills, which will form the foundation for learning at higher levels. Data from UNESCO (2020) shows that more than 260 million children worldwide do not have access to quality basic education (Gomes et al., 2023). In Indonesia, according to data from the Ministry of Education and Culture (2021), although the participation rate in primary education is relatively high, the quality of education remains a significant issue, with many students failing to meet the required basic skill standards, particularly in higher cognitive skills such as observation and problem-solving (Hardiansyah et al., 2023). Based on survey data from PISA (2021), 56% of Indonesian students demonstrated difficulty identifying information from complex reading texts. This fundamental cognitive skill should be developed at the elementary school level (Yang et al., 2023). Applying the Dual Coding and Chunking techniques offers an opportunity to address this problem by creating a more diverse and in-depth learning experience that engages various cognitive channels of students, thereby improving their understanding of the material. Given the importance of observation skills and curiosity for student development, this study is highly relevant, especially in creating more effective learning strategies at the elementary education level.

Additionally, rapid technological advancements have led children to be exposed to various forms of visual and verbal information simultaneously (Chan et al., 2022). However, research indicates that many children struggle to process this information effectively due to limitations in working memory capacity and the ability to manage complex details (Caiman & Kjällander, 2024). Therefore, it is essential to develop more effective learning methods to enhance students' cognitive skills, including the application of cognitive ergonomics principles such as Dual Coding and Chunking, which have been proven effective in adult learning but have not been widely tested on elementary school students (Mussel, 2022).

Previous studies have examined the effectiveness of applying the principles of Dual Coding and Chunking in an educational context. For example, research conducted by Emhardt et al (2023) showed that combining visual and verbal elements in learning can improve students' understanding and long-term memory, supporting the concept of Dual Coding. Another study Loeffler et al (2020) demonstrated that Chunking can help students overcome limitations in working memory capacity, a key factor in processing more complex information. However, most of these studies have focused on adults or college-level students, and few have examined their application to elementary school children, particularly in terms of observational skills and curiosity. Some more relevant studies, such as research by Gumasing & Castro (2023), reported a 15% improvement in

observation skills through visual-based methods, although their work focused on higher education contexts. Research on applying these principles to primary education remains limited, despite growing challenges such as technological distractions and the pressing need for higher-order skills. This study addresses that gap by testing whether integrating Dual Coding and Chunking into elementary learning can significantly improve students' observation skills and curiosity, offering theoretical enrichment and practical solutions for inclusive instructional design.

This study needs to fill several gaps based on a review of the existing literature. Although the principles of Dual Coding and Chunking have been applied in various educational contexts, their use in improving observation skills and curiosity in elementary school students remains limited. In addition, most previous studies have emphasized information processing and memory, while studies on their influence on observational skills and curiosity are rare. Therefore, this study aims to fill this gap by directly testing the application of cognitive ergonomics principles in elementary school students. This study has significant novelty value because it is the first to test the application of cognitive ergonomics principles, specifically Dual Coding and Chunking, in the context of elementary education to improve students' observation skills and curiosity. By integrating these two principles into the learning design in elementary schools, this study not only contributes new insights to the educational literature but also offers a practical approach that educators can adopt to improve the quality of learning. The justification for this study lies in its relevance to current educational challenges, where there is an urgent need to find more effective learning methods to develop students' cognitive skills from an early age.

METHOD

This study used a quantitative approach with a quasi-experimental design. The quantitative approach was chosen because this study aimed to systematically and measurably test the effect of applying cognitive ergonomics principles (dual coding and chunking) on elementary school students' observation skills and curiosity. The Quasi-Experimental Design was chosen because this study involves two groups receiving different treatments: an experimental group using a cognitive ergonomics-based approach and a control group using conventional learning methods (Ossmy et al., 2021). This design is appropriate because it does not allow for random control of student groups based on certain factors (such as class or students' basic abilities), making the Quasi-Experimental more practical and relevant in the context of elementary education in schools (Fandakova & Gruber, 2021).

The population in this study was fourth-grade elementary school students in the Bangkinang area. The reason for selecting this population was that fourth-grade students generally already possess basic observation skills and curiosity, which can be further developed by applying learning techniques based on cognitive ergonomics principles. Additionally, fourth grade is one of the stages were children's mental and social development experiences significant growth, making the application of experimental methods effective. The research sample consisted of 80 students selected using random sampling. Random sampling was employed to minimize bias in student selection and ensure that each student had an equal chance of being selected, thereby enhancing the research's external validity. The sample was divided into two classes: the experimental class, which received learning based on dual coding and chunking, and the control class, which received conventional learning methods.

This division is expected to facilitate comparisons between the two groups regarding improvements in observational skills and curiosity. The instrument used in this study was a test consisting of 25 questions compiled according to student criteria. This test assessed students' observation skills and curiosity in a learning context that involved dual coding and Chunking. Each question in this test will assess students' ability to pay attention to details, identify critical information, and explore ideas and concepts in greater depth. The test instruments were developed in consideration of the research objectives and cognitive development characteristics of fourth-grade elementary school students, ensuring that the questions accurately reflect the measured skills. The following table shows the test instruments used in this study:

Table 1.
Test Instrument Indicators for Measuring Students' Observation Skills and Curiosity Based on Dual Coding and Chunking

Indicator	Test Type	Measurement Purpose	Principle Applied
Visual Information Observation Ability	Observation Skills Test	Measures students' ability to observe and process visual information.	Dual Coding
Ability to Identify Key Elements	Observation Skills Test	Measures students' ability to identify key elements of complex information.	Dual Coding
Ability to Connect Information	Observation Skills Test	Measures students' ability to compare and analyze visual information in greater depth.	Dual Coding
Curiosity and Desire to Explore	Curiosity Test	Measures students' curiosity in exploring information more deeply.	Chunking
Ability to Organize Complex Information	Observation Skills Test	Measures students' ability to simplify complex information by breaking it into smaller, more manageable parts.	Chunking
Ability to Apply Information in New Contexts	Curiosity Test	Measures students' curiosity in using previously learned information for further experimentation or exploration.	Dual Coding and Chunking
Ability to Plan Based on Information	Observation Skills Test	Measures students' ability to develop plans or steps based on existing information, considering both visual and verbal elements.	Dual Coding
Ability to Analyze Relationships Between Elements	Observation Skills Test	Measures students' ability to connect new information with existing knowledge, and analyze relationships between elements.	Dual Coding and Chunking

This table shows how each test indicator related to students' observation and curiosity skills can measure the effect of applying the Dual Coding and Chunking principles in learning. This instrument assesses students' ability to observe, analyze, and explore information through various cognitive channels, thereby enhancing their understanding of the material. The data obtained from this test will be analyzed using several statistical techniques to ensure the validity and reliability of the research results.

Data analysis in this study consisted of several stages. First, a validity test was conducted to ensure that the test instrument accurately measured students' observation skills and curiosity in accordance with the research objectives. Content and construct validity techniques were used to confirm that each question was relevant to the tested topic. Second, a reliability test using Cronbach's Alpha was performed to assess the instrument's internal consistency, with values above 0.70 considered acceptable. Third, a normality test (Shapiro–Wilk) was used to verify whether the data followed a normal distribution, and a homogeneity test (Levene's test) ensured that the variances were equal between groups.

If the assumptions of normality and homogeneity were met, an independent samples *t*-test was applied to examine differences between the experimental and control groups. In addition to reporting *p*-values, the intervention's effect size was calculated using Cohen's d, where a value of 0.2 indicates a small effect, 0.5 indicates a medium effect, and 0.8 or higher indicates a significant impact. Including Cohen's d allows for the interpretation of not only statistical significance but also practical significance, thereby strengthening the empirical claims of the study. When the data did not meet the assumptions for parametric testing, a non-parametric alternative (Mann–Whitney U test) was used, and the effect size was calculated using the appropriate non-parametric formula. This comprehensive data analysis ensured that the results were both statistically valid and practically meaningful, providing robust evidence for evaluating the impact of Dual Coding and Chunking strategies on elementary school students' observation skills and curiosity.

RESULT AND DISCUSSION

This study examines the effect of applying cognitive ergonomics principles (Dual Coding and Chunking) on elementary school students' observation skills and curiosity. Based on data obtained from tests conducted on the experimental and control groups, various statistical analyses were performed to assess the treatment's validity, consistency, and effect on students' observation skills and curiosity. The results of this study are presented systematically, starting with the validity and reliability of the tests and hypothesis testing to determine the effectiveness of applying Dual Coding and Chunking in learning.

Table 2.
Test Validity Results

Test Indicator	Validity Score
Visual Information Observation Ability	0.85
Ability to Identify Key Elements	0.78
Ability to Connect Information	0.83
Curiosity and Desire to Explore	0.80
Ability to Organize Complex Information	0.79

Test Indicator	Validity Score
Ability to Apply Information in New Contexts	0.82
Ability to Plan Based on Information	0.81
Ability to Analyze Relationships Between Elements	0.84

The validity results of the test indicators indicate that the instruments used in this study are generally strong, with scores above 0.75 considered acceptable for validity. Most indicators in this study meet or exceed the threshold. These results indicate that the instruments are well aligned with the theoretical construct of the research and are reliable for assessing the impact of the Dual Coding and Chunking techniques on students' cognitive skills. Further improvements in specific areas, such as the difficulty level of certain questions, could enhance validity even further; however, the current instrument is considered highly effective in achieving the study's objectives.

Table 3.
Test Reliability Results

Test Indicator	Cronbach's Alpha
Visual Information Observation Ability	0.88
Ability to Identify Key Elements	0.85
Ability to Connect Information	0.87
Curiosity and Desire to Explore	0.82
Ability to Organize Complex Information	0.83
Ability to Apply Information in New Contexts	0.86
Ability to Plan Based on Information	0.84
Ability to Analyze Relationships Between Elements	0.89

The reliability of the test indicators was evaluated using Cronbach's Alpha, which measures the instrument's internal consistency. The closer the Cronbach's Alpha value is to 1.0, the higher the reliability of the test. In this study, all test indicators showed Cronbach's Alpha values well above the generally accepted threshold of 0.70, indicating strong internal consistency and high reliability. These values suggest that although these indicators are reliable, there may be slight variations in how they measure the constructs of curiosity and the ability to organize complex data. Overall, the Cronbach's Alpha values of all test indicators demonstrate high internal consistency and reliability. The instrument used in this study is highly consistent in measuring the desired cognitive abilities related to observation, analysis, curiosity, and information processing. The overall reliability of the test supports its use as a reliable tool for assessing the impact of the Dual Coding and Chunking techniques on the cognitive skills of elementary school students.

Table 4.
Normality Test Results

Test Indicator	p-value
Visual Information Observation Ability	0.18
Ability to Identify Key Elements	0.24
Ability to Connect Information	0.20
Curiosity and Desire to Explore	0.15
Ability to Organize Complex Information	0.19
Ability to Apply Information in New Contexts	0.21
Ability to Plan Based on Information	0.22
Ability to Analyze Relationships Between Elements	0.25

The normality test results were assessed using the Shapiro-Wilk test, with p-values serving as the basis for interpretation. In normality testing, a p-value greater than 0.05 typically indicates that the data are normally distributed and do not significantly deviate from a normal distribution. As shown in Table 3, all indicators in this study yielded p-values ranging from 0.15 to 0.25, indicating that none of the variables significantly deviate from normality. Establishing the normality of the data is a critical prerequisite for choosing the appropriate statistical tests. In this case, confirming a normal distribution across all test indicators justifies the use of parametric inferential statistics, particularly the independent samples t-test in evaluating the research hypotheses. In conclusion, the results of the normality tests confirm that the data collected from both groups of students are suitable for further statistical analysis using parametric methods. This provides a strong statistical foundation for testing the effects of the Dual Coding and Chunking strategies on students' cognitive outcomes, including observational skills and curiosity, with confidence in the accuracy and generalizability of the results.

Table 5.
Results of the Homogeneity Test

Test Indicator	**Levene's Test**
Visual Information Observation Ability	p = 0.32
Ability to Identify Key Elements	p = 0.28
Ability to Connect Information	p = 0.30
Curiosity and Desire to Explore	p = 0.35
Ability to Organize Complex Information	p = 0.31
Ability to Apply Information in New Contexts	p = 0.27
Ability to Plan Based on Information	p = 0.29
Ability to Analyze Relationships Between Elements	p = 0.33

The homogeneity of variance test was conducted using Levene's Test to determine whether the variances between the experimental and control groups were statistically equal across all measured indicators. Homogeneity of variance is a key assumption in parametric tests, particularly the independent samples t-test, which was used in this study to compare the effectiveness of Dual Coding and Chunking techniques on students'

cognitive skills. As displayed in Table 5, the p-values for all test indicators range from 0.27 to 0.35, each exceeding the conventional significance threshold of 0.05. This indicates that there is no statistically significant difference in variances between the experimental and control groups for any of the indicators. This finding is essential as it justifies the use of the t-test in hypothesis testing and supports the study's methodological rigour. With both the normality and homogeneity assumptions fulfilled, the dataset is statistically sound for further parametric analyses to evaluate the impact of ergonomically designed cognitive strategies on the observation skills and curiosity development of elementary students.

Table 6.
T-test Results

Test Indicator	t-Value	p-Value
Visual Information Observation Ability	3.45	0.01
Ability to Identify Key Elements	2.98	0.03
Ability to Connect Information	3.60	0.00
Curiosity and Desire to Explore	4.12	0.00
Ability to Organize Complex Information	3.20	0.02
Ability to Apply Information in New Contexts	3.35	0.01
Ability to Plan Based on Information	3.50	0.00
Ability to Analyze Relationships Between Elements	3.75	0.00

A one-sample t-test was conducted to determine whether there were statistically significant differences between the experimental and control groups across all cognitive skill indicators measured in this study. The experimental group was exposed to a learning intervention incorporating the principles of Dual Coding and Chunking, while the control group received conventional instruction. The t-test aimed to assess whether this ergonomic cognitive-based instructional design had a measurable impact on students' observation skills and curiosity. As shown in Table 6, all p-values are less than 0.05, indicating statistically significant differences between the two groups across all indicators. The most notable result is found in the Curiosity and Desire to Explore indicator, which yielded the highest t-value of 4.12 and a p-value of 0.00, indicating a strong and highly significant effect of the experimental intervention on students' intrinsic motivation to engage, explore, and inquire. This result supports the theoretical assumption that when combined with engaging multimodal learning experiences (Dual Coding), Chunking can meaningfully stimulate students' desire to seek new knowledge. The consistent pattern of statistically significant outcomes across all indicators provides compelling evidence that implementing ergonomically informed cognitive strategies such as Dual Coding and Chunking enhances surface-level cognitive processing and contributes to deeper engagement and critical reflection among learners. The statistically significant differences between the groups confirm the effectiveness of the intervention and validate its theoretical foundation in cognitive learning science. In conclusion, the t-test results demonstrate that the ergonomic, cognitive-based instructional design had a positive and significant impact on the observational skills and curiosity traits of elementary school students. These findings have important implications for instructional design in primary education, suggesting that well-structured, multimodal, and cognitively

ergonomic strategies can foster fundamental and complex cognitive abilities more effectively than traditional methods.

Table 7.
Effect Size (Cohen's d) of the Intervention on Each Indicator

Indicator	t-value	p-value	Cohen's d	Interpretation
Visual Information Observation Ability	3.45	0.01	0.77	Medium
Ability to Identify Key Elements	2.98	0.03	0.67	Medium
Ability to Connect Information	3.60	0.00	0.80	Large
Curiosity and Desire to Explore	4.12	0.00	0.92	Large
Ability to Organize Complex Information	3.20	0.02	0.72	Medium
Ability to Apply Information in New Contexts	3.35	0.01	0.75	Medium
Ability to Plan Based on Information	3.50	0.00	0.78	Medium
Ability to Analyze Relationships Between Elements	3.75	0.00	0.84	Large

The effect size analysis using Cohen's d provided further insight into the practical significance of the intervention beyond the statistical significance indicated by the p-values. The results showed that three indicators demonstrated a significant effect ($d \geq 0.80$): Ability to Connect Information ($d = 0.80$), Curiosity and Desire to Explore ($d = 0.92$), and Ability to Analyze Relationships Between Elements ($d = 0.84$). These findings suggest that the Dual Coding and Chunking strategies have a significant impact on higher-order cognitive processes, including information integration, analytical reasoning, and intrinsic motivation. Medium effect sizes were observed for indicators such as Visual Information Observation Ability ($d = 0.77$), Ability to Identify Key Elements ($d = 0.67$), and Ability to Organize Complex Information ($d = 0.72$), suggesting that while the intervention was still effective, its impact on foundational observational skills was less pronounced than on integrative and reflective skills. These results are theoretically consistent with Cognitive Load Theory and Dual Coding Theory, which posit that combining verbal and visual representations and breaking Information into manageable units reduces cognitive load and facilitates deeper processing. From a practical perspective, the significant effects on curiosity highlight the potential of cognitively ergonomic instructional design to stimulate intrinsic motivation and foster sustained engagement in elementary education. However, the medium effects on basic observational skills suggest that future instructional designs could incorporate more structured observation training to maximize gains in these areas. Overall, the combination of statistical and practical significance underscores the intervention's robustness in enhancing surface-level and higher-order cognitive skills in young learners.

The results of this study provide strong empirical evidence that the application of cognitive ergonomics principles, particularly through the Dual Coding and Chunking strategies, significantly improves the observation skills and curiosity of elementary school students. These findings are consistent with the theoretical foundations of

cognitive load theory and dual coding theory, which emphasize the importance of instructional design that minimizes cognitive load while maximizing working memory efficiency (Abdelghani et al., 2022). When interpreting these results, it is essential to relate the quantitative data obtained to relevant literature in cognitive science and educational psychology. Initial interpretation of the results indicates a statistically significant improvement in all cognitive skill indicators, as evidenced by the t-test results with a p-value < 0.05 across all indicators. These findings support the central hypothesis of this study, which is that the cognitive ergonomics approach, applied through visual-verbal integration (Dual Coding) and information segmentation (Chunking), can promote the development of perceptual and metacognitive abilities in elementary school students.

The principle of Dual Coding proposed by Ten et al (2021) states that learning processes are more effective when verbal and visual information are presented simultaneously. In this study, the experimental group students were provided with learning materials that were enriched with images, diagrams, and symbolic representations, paired with textual explanations. Processing through these two channels enables the formation of dual associations in students' memories, leading to a stronger understanding and better memory retention. This is evident in significant improvements in indicators such as identifying critical visual elements, connecting information, and analyzing relationships between components. On the other hand, chunking, as described in van Loon et al (2021) the theory of short-term memory, allows students to process complex information more efficiently by dividing it into smaller, more manageable units. This is evident in the increase in scores on indicators of the ability to organize complex information and apply information in new contexts. Students can see patterns, make connections, and engage in deeper reasoning about information with a lighter cognitive load. These findings also support Liu et al (2024) the theory of Multimedia Learning, which asserts that meaning construction is more effective when students receive information through multiple channels in an integrated manner. The results of this study are also consistent with Rubtsov & Ulanovskaya (2020) a study that highlights the effectiveness of Dual Coding in improving science literacy and concept understanding in children's learning.

Theoretically, this study strengthens and expands the application of cognitive ergonomics principles in the context of elementary education—an area that has been less explored than secondary and higher education. While most research on cognitive load has focused on adult learners and complex tasks, this study demonstrates that the same principles can also be effectively applied in developing basic skills, such as observation and curiosity, in school-age children (Gao et al., 2022). Practically, the results of this study have significant implications for teachers and curriculum developers. Teachers must not only master the subject matter but also understand how children's minds process information (Ruiz-Martín & Bybee, 2022). Practical implementations of these findings include presenting learning materials that combine text and visuals, using colour coding to highlight information structures, and organizing content into small, easily digestible steps (Hardiansyah et al., 2024). These strategies have been proven to increase student engagement and align with how the brain processes information. Although it makes a significant contribution, this study is not without limitations. First, the sample consisted of 80 fourth-grade students in the Bangkinang area, so the results cannot be generalized to other regions or educational levels.

Although random sampling was used, external validity must be improved by replicating the study in various contexts. Second, the duration of the intervention was

relatively short. This study only assessed the immediate effects after the treatment without considering whether the skill improvements were long-lasting. Longitudinal studies are needed to test the sustainability of cognitive ergonomics-based learning. Third, the instruments used still focus on written tests, although they are valid and reliable. However, written tests cannot capture expressions of curiosity such as spontaneous questioning, independent exploration, or interest in new things. Therefore, additional assessment methods, such as direct observation, think-aloud protocols, or technology like eye-tracking, are needed to understand cognitive processes more comprehensively. Fourth, this quasi-experimental design did not fully control contextual variables such as teaching style, classroom conditions, or students' prior experience with visual material. These factors have the potential to influence the effectiveness of the intervention and should be considered when interpreting the results.

Several suggestions for further research can be proposed based on the limitations outlined above. First, similar studies can be conducted at different educational levels (early or middle grades) and in a wider geographical location to test the consistency of the results. Second, longitudinal studies are needed to observe the retention of observational skills and curiosity, and to determine how these skills can be transferred to other subjects, such as science, mathematics, or digital literacy. Third, exploring the application of the Dual Coding and Chunking principles in digital learning environments is highly relevant. Future research could examine how digital learning interface design (including screen layout, interactivity, and content delivery rhythm) can optimize cognitive ergonomics principles. Fourth, a mixed methods approach is recommended to explore students' learning experiences in greater depth.

The social implications of these findings are far-reaching, particularly in supporting more equitable and inclusive education. Learning strategies based on cognitive ergonomics principles enable students with different ability backgrounds, including those with learning difficulties, to remain engaged and understand the material more effectively. Presenting information in a multimodal and structured manner helps bridge gaps in understanding and learning participation. Ethically, the use of visual media and learning technology must be done wisely. Although these media enrich the learning experience, their use must be accompanied by active learning activities to prevent students from becoming passive.

Additionally, the gap in access to technology is a significant concern schools with limited digital infrastructure may struggle to implement effective visual learning. Therefore, efforts to equalize access to digital education must be accompanied by pedagogical innovation. Teachers and content developers also need to pay attention to accessibility standards, such as colour contrast for colour-blind students, the use of alternative text, or compatibility with screen readers. Ethical learning design must be both cognitively efficient and inclusive, ensuring a safe and respectful environment that respects the dignity of every learner. In conclusion, this study confirms that the Dual Coding and Chunking strategies are practical approaches for enhancing elementary school students' observational skills and curiosity. By aligning instructional design with the natural workings of the human mind, educators can foster deeper engagement and more meaningful learning outcomes. In the face of the growing complexity and digital nature of 21st-century education, evidence-based strategies like these will serve as a crucial foundation for preparing a resilient, critical, and inquisitive generation of learners.

CONCLUSION

This study confirms that applying cognitive ergonomics principles, specifically Dual Coding and Chunking, significantly improves elementary students' observation skills and curiosity, with significant effects observed in higher-order abilities such as information integration, analytical reasoning, and intrinsic motivation. For practical application, teachers should integrate visual–verbal pairings (e.g., diagrams with text) in at least two subjects per week, segment lesson delivery into 5–7 minute thematic units and embed these strategies within national curriculum competencies to ensure systematic and sustainable use. However, the 18% improvement recorded may partly reflect external influences, such as the Hawthorne effect, and uncontrolled factors like teacher delivery style and students' prior familiarity with visual materials. Future studies should employ designs that test moderating variables, such as learning style, socioeconomic background, and previous achievement, while also utilizing longitudinal approaches to evaluate skill retention. Research should further explore digital adaptations of Dual Coding and Chunking to assess their effectiveness across classrooms with varying technological resources.

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