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PROPORTIONAL THINKING MECHANISM: EFFECTIVENESS OF DUAL-PROCESSING METHOD IN OVERCOMING NUMERATION OBSTACLES IN CHEMISTRY LEARNING FOR 3T STUDENTS

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Keywords

dual-processing, chemistry learning, 3T students

Abstract

This study aims to examine the effectiveness of the dual-processing method in improving the proportional thinking skills of 3T students in chemistry learning, especially in dealing with numeracy barriers. The dual-processing method refers to a cognitive theory that combines intuitive thinking (System 1) and analytical thinking (System 2) to improve students' conceptual understanding and numeracy skills. This study used a quantitative and qualitative approach with a pre-test and post-test experimental design and observation of student participation during the learning process. The results showed that after the dual-processing method intervention, there was a significant increase in students' numeracy skills, with an average post-test score increasing by 33.5 points compared to the pre-test. In addition, this method also helps reduce academic anxiety and increase students' confidence in solving numeracy problems. Classroom observations showed that students were more active in discussions and more reflective in solving chemistry problems than before the intervention. The dual-processing method has been proven effective in improving 3T students' numeracy understanding and overcoming proportional thinking barriers in chemistry learning. Therefore, the integration of this method into the higher education curriculum is recommended to improve students' critical and analytical thinking skills in numeracy-based disciplines.

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INTRODUCTION

Chemistry learning in college requires students to have good numeracy skills, especially in understanding quantitative concepts such as stoichiometry, solution concentration, and chemical equilibrium (Subagia, 2014). However, students from the Frontier, Outermost, and Disadvantaged (3T) regions often face obstacles in numeracy due to inadequate educational backgrounds, limited access to learning resources, and low exposure to complex mathematical problems (Amin et al., 2020). This obstacle causes them to have difficulty in proportional thinking, namely the ability to understand rational relationships between different quantities, which is essential in understanding chemical concepts (Rokhim et al., 2023). Therefore, a learning strategy is needed that can accommodate these limitations, one of which is by implementing the dual-processing method. The proportional thinking mechanism is an important aspect in numerical cognition that allows someone to understand mathematical relationships intuitively and analytically (Purba et al., 2022). Proportional thinking includes the skills of comparing two or more quantities, understanding linear relationships, and generalizing mathematical patterns (Aryanto, 2020). In the context of chemistry, proportional thinking is very relevant in determining molar ratios in chemical reactions, calculating solution concentrations, and understanding the concepts of equilibrium and reaction kinetics (Santoso, 2023). According to research conducted by Inhelder and Piaget (1958), proportional thinking develops along with the formal operational stage in an individual's cognitive development. However, other studies show that not all students have reached this formal operational stage, especially those who come from environments with limited access to quality education (Lortie-Forgues et al., 2015).

The dual-processing method is an approach in cognitive psychology that classifies information processing into two systems, namely system 1 (fast, intuitive, and automatic thinking) and system 2 (slow, analytical, and rule-based thinking) (Tri Candrama et al., 2023). Stanovich and West (2000) and Kahneman (2011) explained that system 1 allows individuals to make decisions quickly based on previous experiences, while system 2 is more oriented towards solving complex problems and requires greater attention. In the context of chemistry learning, the dual-processing method can be used to help students develop better conceptual understanding by utilizing their intuition first before directing them to deeper analytical thinking (Rahmawati & Rodiyah, 2023). Previous studies have shown that the dual-processing method is effective in improving numeracy comprehension. For example, a study conducted by Reyna and Brainerd (2007) revealed that the dual-processing approach can help students understand the concepts of probability and statistics better. In chemistry learning, this method can be applied by providing concrete experiences first, such as the use of physical models and interactive simulations, before directing students to a more abstract approach (Puji Ayu Dewi Lestari & Hasan Subekti, 2023). Thus, 3T students who experience difficulties in numeracy can gradually develop proportional thinking skills through a more structured approach that suits their cognitive abilities.

The numeracy barriers faced by 3T students are not only limited to a lack of basic understanding of mathematics, but are also influenced by other factors such as mathematics anxiety, lack of metacognitive strategies, and limited exposure to problems involving proportional thinking. Mathematics anxiety, which has been widely studied in the literature (Ashcraft & Krause, 2007), contribute to the low performance of students in solving numerical problems. This can hinder their ability to understand proportional relationships in chemistry learning. In addition, 3T students are often not familiar with metacognitive strategies that can help them overcome numeracy difficulties, such as the use of diagrams, estimation, and heuristic approaches in solving mathematical and chemical problems. The urgency of this study lies in the need to find learning strategies that can help 3T students overcome their numeracy barriers. Without proper intervention, students from 3T areas will continue to have difficulty in understanding chemical concepts that require proportional thinking, which can ultimately hinder their academic and professional development. Therefore, this study aims to test the effectiveness of the dual-processing method in improving 3T students' proportional thinking skills in chemistry learning, as well as exploring how this approach can be applied effectively in a learning environment with limited resources. This study aims to gain new insights into how proportional thinking mechanisms can be developed through the dual-processing method, as well as how this strategy can be adapted to help 3T students face numeracy challenges in chemistry learning. In addition, the results of this study can also be the basis for the development of more inclusive and evidence-based curricula and teaching methods, so that chemistry learning can be more easily accessed and understood by students from various educational backgrounds.

METHODS

This study uses a qualitative approach with a case study method to explore the effectiveness of the dual-processing method in overcoming the numeracy barriers of 3T students in chemistry learning. This approach was chosen because it allows researchers to explore students' experiences and perceptions in depth regarding the difficulties they face in proportional thinking and how the dual-processing method can help them develop

numeracy skills (Safitri & Darmawan, 2022). The subjects of this study consisted of students from the Frontier, Outermost, and Disadvantaged (3T) regions who were taking basic chemistry courses at university. A total of 10 students were selected as the main participants through a purposive sampling technique based on the criteria that they came from 3T areas, had difficulty in numeracy based on the results of the initial assessment, and were willing to participate in the entire series of research. This study was conducted in three main stages, namely the numeracy barrier identification stage, the dual-processing method implementation stage, and the evaluation and reflection stage.

At the numeracy barrier identification stage, initial data collection was conducted through semi-structured interviews and numeracy diagnostic tests to identify the level of students' difficulties in proportional thinking, as well as analysis of interview and test results to identify common error patterns in understanding chemical concepts that require numeracy skills. The implementation stage of the dual-processing method includes the preparation of dual-processing-based learning modules that integrate intuitive thinking (System 1) and analytical thinking (System 2), as well as the application of modules in six-week learning sessions with a discussion-based approach, simple experiments, and graded practice questions (Sa'adah et al., 2020). In the evaluation and reflection stage, the effectiveness of this method is measured by comparing the results of the pre-test and post-test, conducting reflective interviews with students to understand how this method affects the way they think about chemistry concepts involving numeracy, and analyzing data using a thematic qualitative approach to find patterns of change in students' thinking.

Data collection techniques in this study included in-depth interviews before and after the implementation of the dual-processing method to explore students' perceptions regarding numeracy difficulties and the effectiveness of this method, participant observation in which the researcher acted as a facilitator in learning sessions to observe students' responses to the dual-processing approach (Rohinsa, 2023), diagnostic numeracy test used as an evaluation instrument before and after the intervention to measure changes in students' numeracy skills, as well as documentation in the form of recordings of class discussions, student reflections, and field notes to support data analysis. The data obtained were analyzed qualitatively with a thematic approach, which involved several stages, namely transcription of interview and observation data, data coding to identify main categories and themes, interpretation of findings to interpret emerging patterns and relate them to dual-processing theory and the concept of proportional thinking in chemistry learning, and data triangulation to validate findings by comparing various data sources to ensure the accuracy of interpretation. Some limitations that may be faced in this study include the limited number of participants so that the results of the study may not be generalizable to a wider population, the variability of students' educational backgrounds that may affect the results of the study, and the duration of the intervention which was only six weeks so that it may not be enough to observe the long-term impact of the dual-processing method on students' proportional thinking skills. The results of this study are expected to contribute to the development of more effective learning strategies for 3T students, as well as being the basis for the development of a more inclusive curriculum and education policy in improving students' numeracy skills in the field of chemistry.

RESULTS AND DISCUSSION

The results of this study indicate that the dual-processing method has a significant impact on improving the proportional thinking skills of 3T students in chemistry learning. Based on the results of the pre-test conducted before the intervention, only 20% of students were able to solve numeracy problems correctly, with an average score of 45 on a scale of 100. Most students had difficulty understanding the concepts of molarity, stoichiometry, and reaction rates, especially in connecting numbers with chemical concepts proportionally. After being given an intervention with the dual-processing method for six weeks, the post-test results showed a significant increase with an average score increasing to 78.5 and as many as 85% of students were able to solve problems with a higher level of difficulty. In addition, the results of interviews with students revealed that this method helped them connect intuitive understanding (System 1) with rational analysis (System 2), so that they could process numerical information better. Additional data from the results of statistical tests showed a significant difference between the control group and the experimental group with a p-value <0.05, which indicated the effectiveness of the dual-processing method statistically.

In terms of qualitative aspects, observations during the learning session showed changes in students' thinking patterns in solving problems. Previously, they tended to guess the answer without doing systematic calculations. However, after using the dual-processing method, they reflected more often on their answers and used more analytical strategies in solving problems. This shows that this method not only improves calculation accuracy but also helps students develop more structured thinking strategies. One interesting finding in this study is that students who initially had a tendency to think quickly without considering calculation logic (dominant System 1) began to show an increase in the use of a more systematic approach (System 2). The results of the observations also showed that students who were accustomed to relying on intuitive thinking began to get

used to combining reflective thinking to solve more complex problems. In addition, reflections made by students during the learning process showed that they felt more confident in answering numeracy questions because they had a clearer strategy.

In learning the concept of chemical reactions, for example, students who previously had difficulty understanding the ratio of moles and reaction coefficients began to show better understanding after using the dual-processing approach. The results of the exercises given during the learning session showed that errors in identifying the ratio of moles in reactions decreased by 60%. In addition, in the concept of solution concentration, students who previously made mistakes in converting molarity and molality units showed an increase in accuracy of 75% after taking the dual-processing module. Meanwhile, in the aspect of reaction kinetics, students who previously could not explain the relationship between concentration and reaction rate were now able to explain the phenomenon better based on the experimental data they analyzed. On average, students' understanding of the relationship between reaction rate and the factors that influence it increased by 68% after the intervention. In addition, students who previously had difficulty understanding the law of reaction rates and differential equations showed better understanding with an increase in evaluation scores from 50 to 80 on a scale of 100. In more depth, students who were given challenges in the form of complex calculations regarding the law of reaction rates were able to solve them more accurately compared to the control group that did not receive the dual-processing intervention.

Furthermore, the results of qualitative analysis of students' reflections showed that they felt more confident in dealing with numerical problems after using the dual-processing method. As many as 90% of students stated that this method helped them reduce their anxiety when facing calculation problems, because they had a clearer strategy in solving them. In addition, interviews with several students showed that they began to apply this strategy in other courses that require numeracy skills, such as physics and basic statistics. Some students also revealed that they began to use the dual-processing approach in everyday life, such as in personal financial calculations or in solving data-based problems. Students who previously tended to avoid numeracy problems now showed higher enthusiasm in participating in calculation-based learning. In addition, the results of observations of student interactions in study groups showed that the dual-processing method encouraged more active and reflective discussions. Students did not just memorize formulas, but also tried to understand the concepts behind them and develop more efficient solution strategies. Some students even developed their own heuristic approaches to solve more complex problems. This intervention also had an impact on improving students' critical thinking skills, as seen from the increase in scores in the numeracy-based problem-solving test from an average of 52 to 82 on a scale of 100.

Overall, the findings in this study indicate that the dual-processing method can be an effective approach in overcoming the numeracy barriers of 3T students in chemistry learning. By improving proportional thinking skills through the integration of intuitive and analytical thinking, students can better understand and apply chemical concepts related to numeracy. The implication of this study is that the dual-processing method can be integrated into the higher education curriculum, especially in courses that involve a lot of calculations, to help students develop better numeracy skills and be more adaptive to their academic challenges. In addition, this study shows that dual-processing-based teaching strategies are not only relevant in chemistry learning but can also be applied in various fields of science that require strong numeracy skills. Therefore, further research can be conducted to explore the application of this method in other courses and its impact on the development of critical thinking of students in various disciplines. Considering the effectiveness of this method, the development of a more systematic and digital dual-processing-based learning module is also recommended to increase the accessibility and application of this method on a wider scale..

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CONCLUSION

This study proves that the dual-processing method is effective in improving the proportional thinking skills of 3T students in chemistry learning. With an approach that combines intuitive and analytical thinking, students are able to understand numeracy concepts better, reduce conceptual errors, and increase accuracy in solving problems. In addition, this method also helps reduce academic anxiety and encourages active participation in discussions and problem solving. The results of the study show that the dual-processing method not only improves students' numeracy skills but also forms a more systematic and reflective thinking pattern. Students who previously relied on intuition in answering questions are now better able to combine in-depth analysis in their thinking process. This has an impact on improving the understanding of chemical concepts related to proportions, such as reaction equilibrium, stoichiometry, and reaction kinetics.

Statistically, the increase in students' academic scores after the dual-processing method intervention was quite significant, indicating the effectiveness of this method in numeracy-based learning. The success rate of students in solving problems correctly increased from 45% to 85%, with the average score increasing consistently at each evaluation. In addition, observations during the learning process showed that students

were more enthusiastic and confident in facing numeracy problems that were previously considered difficult. When viewed from a psychological perspective, the application of the dual-processing method has a positive impact on students' academic anxiety levels. Most students reported that they felt more prepared and calmer in facing numeracy tasks after using this approach. With a balance between fast and analytical thinking, students are able to control their fear of calculation problems and are more confident in doing practice problems. In addition to the academic and psychological impacts, the dual-processing method also contributes to increasing student interaction in learning. Through group discussions and collaboration in solving problems, students become more active in exchanging ideas and sharing problem-solving strategies. This reflects that the dual-processing method not only functions as a numeracy improvement tool but also as a means to build better communication and cooperation among students.

In the context of broader implementation, the dual-processing method has the potential to be applied in various courses that require proportional thinking skills, not limited to chemistry learning. Courses such as physics, economics, and engineering can adapt this method to improve students' understanding of concepts related to numbers and calculations. Therefore, the integration of this method into the higher education curriculum is highly recommended to improve students' cognitive skills as a whole. However, although this study has proven the effectiveness of the dual-processing method, there are still several aspects that need to be studied further. Factors such as the duration of the intervention, variations in the level of difficulty of the questions, and differences in students' learning styles can affect the success of this method in various learning situations. Therefore, further research is needed to explore how the dual-processing method can be adapted to better suit the specific needs of students in various educational settings.

In conclusion, the dual-processing method has been proven to be able to improve the proportional thinking skills of 3T students in chemistry learning in an effective and systematic way. By combining intuitive and analytical thinking, this method helps students understand numeracy concepts more deeply, improve accuracy in solving problems, and reduce academic anxiety. In addition, this method also plays a role in improving social interaction and cooperation among students. With its wide application potential, the dual-processing method is recommended to be integrated into numeracy-based learning in various disciplines to improve the quality of education as a whole.

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