p-ISSN: 2086-4280
e-ISSN: 2527-8827

Cognitive Conflict Strategy: Mathematical Representation Based on Cognitive Style

Mohamad Salam

Mathematics Education, Universitas Halu Oleo
Kendari, Sulawesi Tenggara, Indonesia
mohamad.salam@uho.ac.id

Article received: 2022-09-20, revised: 2023-01-17, published: 2023-04-30

Abstrak

Kajian ini bermaksud untuk mendeskripsikan jenis representasi matematis siswa berdasarkan gaya kognitif dalam menyelesaikan masalah integral setelah diberikan pembelajaran strategi konflik kognitif. Penelitian ini merupakan penelitian eksploratif dengan menggunakan pendekatan deskriptif-kualitatif. Subjek penelitian ini adalah mahasiswa Jurusan Pendidikan Matematika Universitas Halu Oleo angkatan tahun 2021 yang terdiri dari satu mahasiswa dengan gaya kognitif reflektif and satu mahasiswa dengan gaya kognitif impulsif. Data penelitian diperoleh melalui teknik pemberian tes and wawancara, and dianalisis secara kualitatif. Hasil yang diperoleh adalah siswa yang memiliki gaya kognitif reflektif dalam menyelesaikan masalah integral setelah diajarkan strategi konflik kognitif adalah melakukan representasi gambar atau representasi geometri, representasi verbal and representasi simbolik, serta melakukan penerjemahan dari berbagai jenis representasi, yaitu dari representasi geometri ke representasi verbal, and kemudian ke representasi simbolik serta sebaliknya. Seandgkan, siswa dengan gaya kognitif impulsif melakukaan representasi simbolik, melakukan representasi geometrik tetapi salah, tidak melakukan representasi verbal, tidak melakukan representasi matematis, and tidak melakukan penerjemahan dari berbagai jenis representasi.
Kata Kunci: Gaya kognitif; representasi matematis; strategi konflik kognitif.

Abstract

This study aimed to describe types of students' mathematical representations based on the cognitive style in solving integral problems after learning cognitive conflict strategies. This exploratory research used a descriptive-qualitative approach. The participants were two students of Mathematics Education Department at Halu Oleo Universit, class of 202, consisting of one student with a reflective cognitive style and one student with an impulsive cognitive style. The research data were obtained through tests and interviews, and analyzed qualitatively. The findings pointed out that the student with a reflective cognitive style performed images or geometric representations, verbal representations, and symbolic representations, as well as translated various types of representations, starting from geometric representations to verbal representations, and then to symbolic representation and vice versa. Meanwhile, the student with an impulsive cognitive style performed symbolic representations, inaccurate geometric representations, but lacked of verbal representations, mathematical representations, and translation of various types of representation.
Keywords: cognitive conflict strategies; cognitive style; mathematical representation.

I. INTRODUCTION

Mathematics is one of the lessons that is objective, logical, and practical (Jawad et al., 2021; Lai et al., 2015) as a symbolic language that allows humans to think about problem solving and utilized to connect one problem to another (Sukardjo & Salam, 2020; Yarmohammadian, 2014), for that reason, teachers must be able to thoroughly observe the problems in the classroom to find appropriate learning patterns in solving problems according to the student's characteristics (Salam et al., 2019). Complex problems could be resolved by visual, symbolic, and verbal representation (Yang & Sianturi, 2022).

Representation is a description of an object in a mathematical equation, computer simulation, picture, graphic, diagram, or in other forms to explain the cognitive process in understanding mathematical ideas (Geyer & Kuske-Janßen, 2019; Sahendra et al., 2018; Salam, 2022), encouraging the students to develop cognitive styles by describing abstract mathematical ideas into sensible forms which assist their comprehension (Sari & Darhim, 2020).

Representation is a factual form of a person's thinking about the problem, and used as a measuring tool to obtain a solution (Inayah & Nurhasanah, 2019; Silviani, Mardiani, & Sofyan, 2021). Mathematical representation is a process to design mathematical models of real problems into mathematical concepts or abstract symbols (Yuanita et al., 2018; Linda & Afriansyah, 2022), with the purpose that it is easier to understand the concept (Kokkonen & Schalk, 2021; Yakubova et al., 2020). The indicators of mathematical representation ability consist of: (1) visual, to present information or data in the form of diagrams, graphs, tables, and drawings or geometric patterns in solving and explaining problems; (2) symbolic, to compile equations or mathematical models and make conjectures on number patterns and solve problems involving mathematical expressions; and (3) verbal, to solve problems in written forms or in the form of stories according to the problems presented (Taofik & Juandi, 2022).

The phenomenon that occurs among students of Mathematics Education Department of Halu Oleo University Kendari showed that the students are having difficulties to represent Integral problems into various mathematical representations (geometric representation, verbal representation, and symbolic representation). The students perform incorrect mathematical representations while solving Integral problems. The students still experience a variety of barriers and errors in solving integrals due to lack of understanding of the concept. Errors in performing representations emerge misconceptions that influence the representations of the problems. Investigating students' misconceptions might be conducted by applying cognitive conflict strategies (Mufit et al., 2020).

A cognitive conflict strategy is a learning process designed to arise mental conflicts on the discrepancy between given information and students' prior knowledge with the purpose that the information affects the students' cognitive structures (Gusnidar et al., 2018; Sundayana & Parani, 2023). Cognitive conflict is an anlogy of discrepancy between the learning condition and the student' cognitive development (Supena et al., 2021; Yustinaningrum & Lubis, 2019), that can be identified by verbal cues or the student' statements towards the conflict (Maharani & Subanji, 2018). One of the cognitive conflict indicators is when the student realizes the discrepancy in the interpretation during their information construction process (Guarana & Hernandez, 2016; Fauzan, Kusnadi, & Sofyan, 2023).

Students who demonstrate cognitive conflict should be resolved immediately because it will interfere with the construction process of further knowledge. The learning process infused by cognitive conflict strategy follows these stages: (1) pre-conflict stage, which is the stage before the conflict, to create a state of cognitive conflict; (2) cognitive conflict stage; and (3) conflict resolution stage, which is the stage of resolving cognitive conflict (Sujana et al., 2019). One of the important stages in the learning process with cognitive conflict strategy is the conflict resolution (Parwati & Suharta, 2020). The key to the successful learning process with cognitive conflict strategy is to assure that students reconstruct the correct concept in developing their knowledge (Calleja & Formosa, 2020), which help them to perform a correct mathematical representation (Parwati & Suharta, 2020).

One of the variables that differs the student' characteristics in mathematics learning is the cognitive style. The cognitive style relies on the veracity of the individual's characteristics in collecting, analysing, storing, thinking, and utilizing the information to solve problems (Kamid et al., 2020). The cognitive style is classified into: reflective and impulsive (Ismaeel & Mulhim, 2021; Shoimah et al., 2018). A student who spends longer time in answering the question, but usually answers carefully and correctly is called reflective cognitive style, whereas a student who spends shorter time to solve the problems, but lacks of careful thought and usually gives incorrect answers is called impulsive cognitive style (Muhtarom et al., 2018; Astutik & Purwasih, 2023).

Various studies on describing the ability to represent mathematical problems has been conducted, to mention: Setyawati (2020), Yenni & Sukmawati (2020), Kusumawarandi & Mega (2021) investigated the students' mathematical representation ability based on self-efficacy, learning motivation, and reflective-impulsive cognitive style; Nurfitriyanti et al. (2020) investigated the students' mathematical representation ability based on mathematical cognition in the problem-based learning process; Azizah et al. (2019) explored the students' mathematical representation ability based on the students' cognitive styles through problem-based learning; and Amalia et al. (2020) investigated the mathematical representation ability based on the cognitive styles after giving problem based learning assisted by Geogebra and realistic mathematics education model.

Based on the above explanation, this study examined the students' ability of mathematical representation in terms of cognitive style after being given cognitive conflict strategy learning and aimed to: (1) describe the types of mathematical representations performed by students with reflective cognitive styles in solving integral problems after completing the cognitive conflict strategy learning process; (2) describe the types of mathematical representations made by students with cognitive-impulsive style in solving integral problems after completing the cognitive conflict strategy learning process.

II. METHOD

This research was an exploratory study using a qualitative approach involving the students of the Department of Mathematics Education, Halu Oleo University, class of 2021 who were taking integral calculus courses.

The participants were selected through some steps: (1) the cognitive style test given to determine the students' impulsive-reflective cognitive styles based on Jerome Kagan (1965), using Matching Familiar Figures Test (MFFT) developed by Warli (2010), consisting of 13 items (Herianto, 2020), (2) the selection of two participants that represented reflective and impulsive cognitive style. The two participants possessed a similar ability in differential calculus.

The data were collected by using tests and interviews. The test consisting of 2 items of integral problems was provided to the participants, as follows:

(1). Calculate $\int_{-2}^{6} f(x)dx$, if :

$$f(x) = \begin{cases} x+2; & -2 \leq x < 0 \\ 2 \quad ; & 0 \leq x < 4 \\ x-2; & 4 \leq x \leq 6 \end{cases}$$

(2). Calculate $\int_{0}^{6} f(x)dx$,

if $f(x) = \begin{cases} |x-2|; & 0 \leq x < 4 \\ 2; & 4 \leq x \leq 6 \end{cases}$.

The interview was conducted to verify the students' answers of the written test. The data, then, were analysed through data reduction, data presentation and conclusion drawing (Sarosa, 2021).

The procedures of this study were : (1) integrating the cognitive conflict learning strategy in the integral lesson regarding "Fundamental Theorems of Calculus", that consists of (a) pre-conflict stage, (b) cognitive conflict stage, and (c) conflict resolution stage, resolving the cognitive conflict, (2) providing the cognitive style test, (3) selecting the participants of the study, (4) providing integral test to the participants, (5) interviewing the participants to verify the test results , (6) validating the data with the triangulation technique by examining the validity of the written test results against the interview results, (7) analysing the data qualitatively, and (8) drawing conclusions.

III. RESULT AND DISCUSSION

A. The participant with reflective cognitive style

Before answering question number 1, the participants with reflective cognitive style were first asked to perform image representation or geometric representation, and the results are presented in Figure 1.

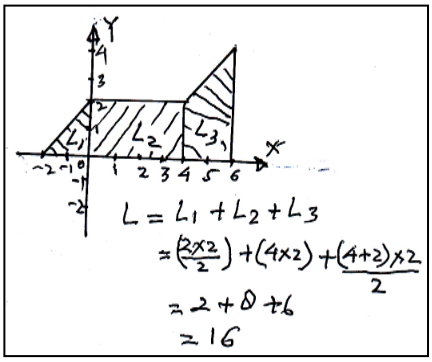

Figure 1. The image representation made by the student with reflective cognitive style on question number 1

According to the image representation in Figure 1, the participant with reflective cognitive style obtained the result of 16 units of area. After representing the problem geometrically, the participant performed a verbal representation, namely explaining the relationship between the problem and the geometric representation that had been made. The participant argued that the integral result of the given function could be found by calculating the area of the bounded area with: (1) line y = x + 2, line x = -2, axis x, and line x = 0; (2) line y = 2, line x = 4, x = 0, and axis x; (3) line y = x - 2, axis x, line x = 4 and line x = 6. According to the geometric representation made, the participant stated that the result of the integral function equalled to the area of triangle L1, the area of rectangle L2, and the area of trapezoid L3.

Furthermore, by using the theorem: $\int_a^c f(x)dx = \int_a^b f(x)dx + \int_b^c f(x)dx$, the participant performed symbolic representation as showed in Figure 2.

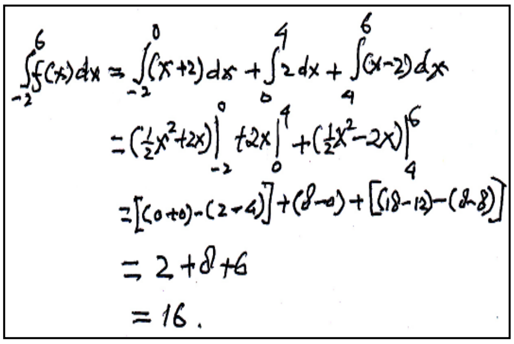

Figure 2. The symbolic representation made by the student with reflective cognitive style on question number 1

Based on the symbolic representation in Figure 2, the participant with reflective cognitive style found similar results with the geometric representation and the verbal representation to solve the problem was 16. Based on the question number 1, the participant translated the geometric representation to verbal representation, the geometric to symbolic representation, and verbal to symbolic representation, or vice versa. It implied that the reflective participant performed one type of representation to another, namely from geometric representation to verbal representation and then to symbolic representation or vice versa.

To answer question number 2, the participant performed visual or geometric representation, illustrated by Figure 3.

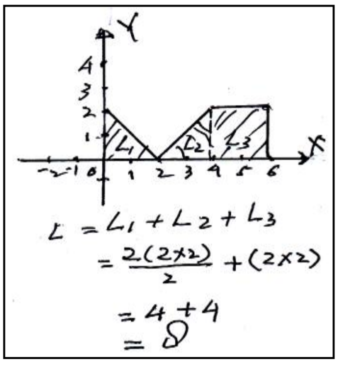

Figure 3. The visual representation made by the participant with reflective cognitive style on question number 2

After drawing geometric representation, the participant performed verbal presentation by explaining the correlation question number 2 with the geometric representation that had been made. The participant argued that the integral results of the formula in question number 2 could be obtained by calculating the area bordered by (1) line y = x - 2, axis x, line x = 0 and line x = 2; (2) line y = - x + 2, axis x, line x = 2 and line x = 4; and (3) line y = 2, axis x, line x = 4 and line x = 6. In other words, the integral result of the formula equaled to the sum of the areas of two triangles (L1+L2) an a rectangular (L3). The result obtained by the participant was 8. Using the theorem $\int_a^c f(x)dx = \int_a^b f(x)dx + \int_b^c f(x)dx$, the participant performed symbolic representation, illustrated by Figure 4.

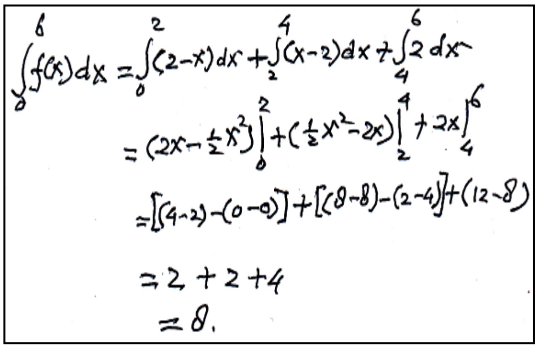

Figure 4. The symbolic representation made by the student with reflective cognitive style on question number 2

B. The participant with impulsive cognitive style

When the participant with impulsive cognitive style was answering question number 1, the participant represented the problem geometrically first, and the result is presented by Figure 5.

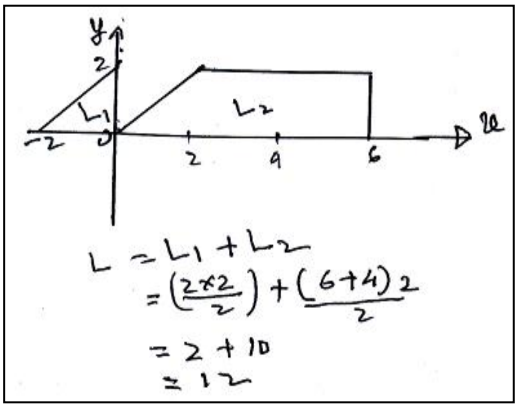

Figure 5. The image representation made by the student with impulsive cognitive style on question number 1

Geometric representation was incorrect because it was not supported by the graph of the function given in the question. The graph was not equal to the graph of the function defined by: (1) line y = x + 2, axis x, line x = -2 and line x = 0; (2) line y = 2, axis x, line x = 0 and line x = 4; and (3) line y = x - 2, axis x, line x = 4 and line x = 6. The participant did not perform verbal representation. Using the theorem: $\int_a^c f(x)dx = \int_a^b f(x)dx + \int_b^c f(x)dx$ the participant obtained the result as showed by Figure 6:

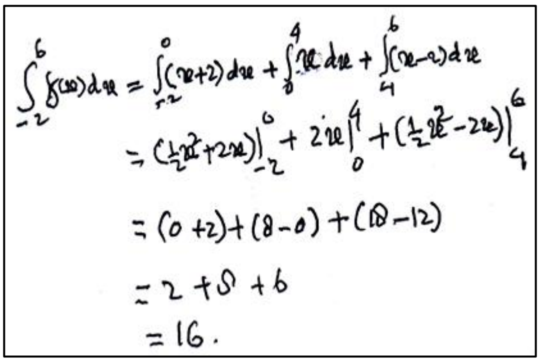

Figure 6. The symbolic representation made by the student with impulsive cognitive style on question number 1

The integral result using symbolic representation was not identical to the integral result using image or geometric representation. The participant was not able to translate one representation to another.

To solve question number 2, the participant graphed the function as the image or geometric representation, illustrated by Figure 7.

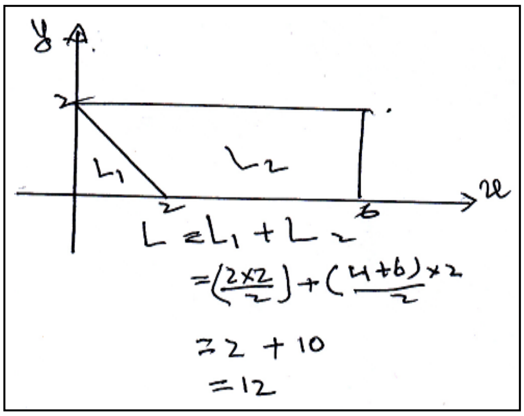

Figure 7. The image representation made by the student with impulsive cognitive style on question number 2

The image made by the participant was not illustrated the graph of the function in question number 2 because it was incorrect. The participant did not perform verbal representation. Using the theorem: $\int_a^c f(x)dx = \int_a^b f(x)dx + \int_b^c f(x)dx$, the participant performed symbolic representation, as illustrated by Figure 8.

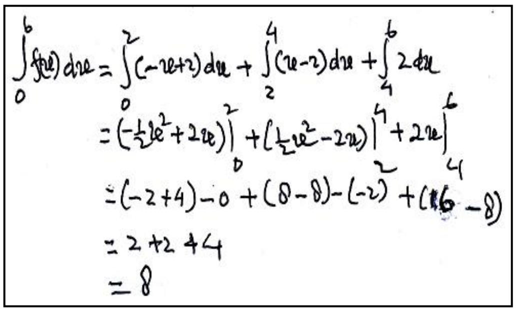

Figure 8. The symbolic representation made by the participant with impulsive cognitive style on question number 2

The integral result from the symbolic representation was not identical with the result from the geometric representation. The participant was not able to translate one type of representation to another one.

C. Discussion

After completing cognitive conflict strategy learning, the participant with reflective cognitive style was able to solve the integral problem accordingly. The participant. The participant could demonstrate conceptual changes for their misconceptions. Based on the correct conceptual understanding, the participant easily performed the geometric, verbal and symbolic representation and translated one representation to another well. The participant obtained the same results in solving the first and second problems by performing geometric, verbal and symbolic representation. The participant made translations from one type of representation to another, namely from geometry representation to verbal representation, then to symbolic representation or vice versa. The participant explained that the basic concept of integral was area and integral could be used to calculate an area.

The implementation of cognitive conflict strategy learning at the stage of conflict resolution could help students with reflective cognitive style construct conceptual changes from misconceptions to the correct concept. This was in line with (Calleja & Formosa, 2020) stating that the result of the cognitive conflict strategy learning aimed to assist student to make conceptual changes. Cognitive conflict strategy learning might impact on improving students' mathematical representation skills because students were encouraged to make conceptual changes to the misconceptions that influenced the mathematical representations. Presenting mathematical ideas through various representations would highly influence the students' mathematical understanding, therefore students were encouraged to practice constructing their own representations to strengthen their skills and conceptual understanding used in solving problems. (Jonassen & Carr, 2020; Rau & Matthews, 2017). The participant with reflective cognitive style represented question number 1 and 2 into various representation conducted slowly and deliberately to generate appropriate representation and solution. It was supported by the individual’s characteristics that solved the problem slowly, but deliberately and gradually in order to get correct answers (Cintamulya, 2019).

The participant with impulsive cognitive style drew geometric representations for problem numbers 1 and 2 incorrectly because there was mathematical misconception that affected the representation of the given problem, for example the concept of drawing linear function graphs had not been mastered by by the participant, according to the results of the interview. The participant could represent problem number 1 and 2 verbally. The participant could represent question number 1 and two into symbolic representation correctly, by applying the theorem: $\int_a^c f(x)dx = \int_a^b f(x)dx + \int_b^c f(x)dx$, the participant was able to determine the solution of question number 1 and 2 correctly. After conceptual changes, the participant comprehended the concept of the absolute value to solve question number 2 symbolically.

After completing cognitive conflict strategy learning, the participant was not able to represent the problem into various representations because his understanding regarding the concepts of mathematical representations was not well developed (Styoningtyas & Hariastuti, 2020), and he was not able to make a connection among mathematical topics (Febrianti Habel & Susilowaty, 2021). The students were encouraging to acquire sufficient understanding and knowledge to represent a mathematical problem. It was in line with Niss & Højgaard (2019) stating that solving mathematical problem required sufficient knowledge and understanding. The participant with impulsive cognitive style did not demonstrate adequate understanding and knowledge of the mathematical concepts underlying the concept of integral material to solve question number 1 and 2. The fact was that when the participant was drawing the geometric representation, he was not able to make the function graph of problem number 1 and 2 correctly, even though the mathematical concepts related to function drawing had been learned in the Differential Calculus course and at the previous education level. Therefore, cognitive conflict strategy learning was applied to the Differential Calculus course, to make conceptual changes on the topic of Function Graphs, by training students to draw various function graphs. The participant solved the given problems into geometric representations quickly, but not thoroughly resulting in incorrect representations. This was supported by the characteristics of the individuals with impulsive cognitive style who usually solve problems quickly, but less accurately which cause a lot of errors (Cintamulya, 2019; Purwaningsih et al., 2019). Impulsive cognitive style was affected by an emotional mind, which demonstrated the nature of being fast but careless (Aini et al., 2020; Purnama et al., 2021).

IV. CONCLUSION

Based on the findings and discussion, the study concluded that the type of mathematical representations made by the student with reflective cognitive style in solving integral problems after being taught with cognitive conflict learning strategy was able to represent images or geometric representations, verbal representations and symbolic representations and translate a various types of representations to another, namely from geometric representations to verbal representations, then symbolic representations and vice versa. Meanwhile, the type of mathematical representation performed by students with impulsive cognitive style in solving integral problems after being taught with cognitive conflict strategy learning was symbolic representation, incorrect geometric representation, but did not perform verbal representation, mathematical representation, and translation of various types of representation.

Based on the conclusions, the researcher recommended teaching integral calculus with the representation of images or geometry, verbal representation, and symbolic representation in explaining the concept and consideration of the cognitive style of students.

REFERENCES

Aini, N., Juniati, D., & Siswono, T. Y. E. (2020). Exploring the combinatorial reasoning of high school students with reflective and impulsive cognitive style in solving problems. *Journal for the Education of Gifted Young Scientists*, *8*(3). https://doi.org/10.17478/JEGYS.768023

Alalouch, C. (2021). Cognitive styles, gender, and student academic performance in engineering education. *Education Sciences*, *11*(9). https://doi.org/10.3390/educsci11090502

Astutik, E. P., & Purwasih, S. M. (2023). Field Dependent Student Errors in Solving Linear Algebra Problems Based on Newman's Procedure. *Mosharafa: Jurnal Pendidikan Matematika*, *12*(1), 169-180.

Chasanah, C., Riyadi, & Usodo, B. (2020). The effectiveness of learning models on written mathematical communication skills viewed from students' cognitive styles. *European Journal of Educational Research*, *9*(3). https://doi.org/10.12973/EU-JER.9.3.979

Chen, Y. T., Liou, S., & Chen, L. F. (2019). The Relationships among Gender, Cognitive Styles, Learning Strategies, and Learning Performance in the Flipped Classroom. *International Journal of Human-Computer Interaction*, *35*(4–5). https://doi.org/10.1080/10447318.2018.1543082

Cintamulya, I. (2019). Analysis of students' critical thinking skills with reflective and impulsive cognitive styles on conservation and environmental knowledge learning. *Asia-Pacific Forum on Science Learning and Teaching*, *20*(1).

Fauzan, B. A., Kusnadi, D., & Sofyan, A. (2023). Changes in Students' Cognitive Abilities through STEM-Based Learning in Elementary Schools. *Mosharafa: Jurnal Pendidikan Matematika*, *12*(1), 89-100.

Guarana, C. L., & Hernandez, M. (2016). Identified ambivalence: When cognitive conflicts can help individuals overcome cognitive traps. *Journal of Applied Psychology*, *101*(7). https://doi.org/10.1037/apl0000105

Herianto. (2020). *Matching Familiar Figures Tes (MFFT)*. 1–8. https://osf.io/34ut8

Ismaeel, D. A., & Mulhim, E. N. al. (2021). The influence of interactive and static infographics on the academic achievement of reflective and impulsive students. *Australasian Journal of Educational Technology*, *37*(1). https://doi.org/10.14742/ajet.6138

Jonassen, D. H., & Carr, C. S. (2020). Mindtools: Affording multiple knowledge representations for learning. In *Computers As Cognitive Tools: Volume II, No More Walls*. https://doi.org/10.1201/9781315045337-8

Kamid, Rusdi, M., Fitaloka, O., Basuki, F. R., & Anwar, K. (2020). Mathematical communication skills based on cognitive styles and gender. *International Journal of Evaluation and Research in Education*, *9*(4). https://doi.org/10.11591/ijere.v9i4.20497

Kokkonen, T., & Schalk, L. (2021). One Instructional Sequence Fits all? A Conceptual Analysis of the Applicability of Concreteness Fading in Mathematics, Physics, Chemistry, and Biology Education. In *Educational Psychology Review* (Vol. 33, Issue 3). https://doi.org/10.1007/s10648-020-09581-7

Lai, Y., Zhu, X., Chen, Y., & Li, Y. (2015). Effects of mathematics anxiety and mathematical metacognition on word problem solving in children with and without mathematical learning difficulties. *PLoS ONE*, *10*(6). https://doi.org/10.1371/journal.pone.0130570

Lin, C. C., Huang, I., & Wu, S. H. (2018). Effects of Dietary Infographics and Cognitive Styles on Learners Information Processing. *Proceedings - 2018 7th International Congress on Advanced Applied Informatics, IIAI-AAI 2018*. https://doi.org/10.1109/IIAI-AAI.2018.00077

Linda, L., & Afriansyah, E. A. (2022). Kemampuan Komunikasi Matematis Siswa Berdasarkan Self-efficacy pada Materi Segiempat dan Segitiga di Desa Sirnajaya. *Journal of Mathematics Science and Computer Education*, *2*(1), 20-43.

Maharani, I. P., & Subanji, S. (2018). Scaffolding Based on Cognitive Conflict in Correcting the Students' Algebra Errors. *International Electronic Journal of Mathematics Education*, *13*(2). https://doi.org/10.12973/iejme/2697

Mufit, F., Asrizal, A., & Puspitasari, R. (2020). Meta-Analysis of the Effect of Cognitive Conflict on Physics Learning. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *6*(2). https://doi.org/10.21009/1.06213

Muhtarom, Sugiyanti, Utami, R. E., & Indriana, K. (2018). Metacognitive ability of male students: Difference impulsive-reflective cognitive style. *Journal of Physics: Conference Series*, *983*(1). https://doi.org/10.1088/1742-6596/983/1/012118

Niss, M., & Højgaard, T. (2019). Mathematical competencies revisited.

Educational Studies in Mathematics, *102*(1). https://doi.org/10.1007/s10649-019-09903-9

Parwati, N. N., & Suharta, I. G. P. (2020). Effectiveness of the implementation of cognitive conflict strategy assisted by e-service learning to reduce students' mathematical misconceptions. *International Journal of Emerging Technologies in Learning*, *15*(11). https://doi.org/10.3991/IJET.V15I11.11802

Purnama, I. M. C. A., Suparta, I. N., & Ardana, I. M. (2021). Analysis of the Mathematical Problem-Solving Characteristics Based on Cognitive Style on Students in the VIII Grade. *Edumatica : Jurnal Pendidikan Matematika*, *11*(02). https://doi.org/10.22437/edumatica.v11i02.11787

Purwaningsih, W. I., Astuti, E. P., Nugraheni, P., & Rizkyaningtyas, N. P. (2019). Characteristics of intuitive thinking in solve mathematical issue based on cognitive style. *Journal of Physics: Conference Series*, *1254*(1). https://doi.org/10.1088/1742-6596/1254/1/012081

Rahim, R. A., Noor, N. M., & Zaid, N. M. (2015). Meta-analysis on element of cognitive conflict strategies with a focus on multimedia learning material development. *International Education Studies*, *13*. https://doi.org/10.5539/ies.v8n13p73

Ramsburg, J. T., & Ohlsson, S. (2016). Category change in the absence of cognitive conflict. *Journal of Educational Psychology*, *108*(1). https://doi.org/10.1037/edu0000050

Rau, M. A., & Matthews, P. G. (2017). How to make 'more' better? Principles for effective use of multiple representations to enhance students' learning about fractions. *ZDM - Mathematics Education*, *49*(4). https://doi.org/10.1007/s11858-017-0846-8

Sabirin, M. (2014). Representasi dalam Pembelajaran Matematika. *Jurnal Pendidikan Matematika*, *1*(2). https://doi.org/10.18592/jpm.v1i2.49

Sahendra, A., Budiarto, M. T., & Fuad, Y. (2018). Students' Representation in Mathematical Word Problem-Solving: Exploring Students' Self-efficacy. *Journal of Physics: Conference Series*, *947*(1). https://doi.org/10.1088/1742-6596/947/1/012059

Salam, M., Ibrahim, N., & Sukardjo, M. (2019). *The Effect of Learning Model and Spatial Intelligence on Learning Outcome*. https://doi.org/10.2991/icamr-18.2019.76

Sari, D. P., & Darhim. (2020). Implementation of react strategy to develop mathematical representation, reasoning, and disposition ability. In *Journal on Mathematics Education* (Vol. 11, Issue 1). https://doi.org/10.22342/jme.11.1.7806.145-156

Sarosa, S. (2021). Analisis Data Penelitian Kualitatif. In *Rajawali Pers*.

Shahbari, J. A., & Peled, I. (2015). Resolving Cognitive Conflict In A Realistic Situation With Modeling Characteristics: Coping With A Changing Reference In Fractions. *International Journal of Science and Mathematics Education*, *13*(4). https://doi.org/10.1007/s10763-014-9509-1

Shoimah, R. N., Lukito, A., & Siswono, T. Y. E. (2018). The Creativity of Reflective and Impulsive Selected Students in Solving Geometric Problems. *Journal of Physics: Conference Series*, *947*(1).

https://doi.org/10.1088/1742-6596/947/1/012023

Silviani, E., Mardiani, D., & Sofyan, D. (2021). Analisis Kemampuan Representasi Matematis Siswa SMP pada Materi Statistika. *Mosharafa: Jurnal Pendidikan Matematika*, *10*(3), 483-492.

Sudia, M., Budayasa, I. K., & Lukito, A. (2014). Profil Metakognisi Siswa Smp Dalam Memecahkan Masalah Terbuka. *Jurnal Ilmu Pendidikan*, *20*.

Supena, I., Darmuki, A., & Hariyadi, A. (2021). The influence of 4C (constructive, critical, creativity, collaborative) learning model on students' learning outcomes. *International Journal of Instruction*, *14*(3). https://doi.org/10.29333/iji.2021.14351a

Sundayana, R., & Parani, C. E. (2023). Analyzing Students' Errors in Solving Trigonometric Problems Using Newman's Procedure Based on Students' Cognitive Style. *Mosharafa: Jurnal Pendidikan Matematika*, *12*(1), 135-144.

Taofik, A. I., & Juandi, D. (2022). Description of Mathematical Representation Ability Through HOTS-Oriented Learning Model: a Systematic Literature Review. *Jurnal Analisa*, *8*(1), 46–56. https://doi.org/10.15575/ja.v8i1.17915

Yakubova, G., Hughes, E. M., & Baer, B. L. (2020). Supporting students with ASD in mathematics learning using video-based concrete-representational-abstract sequencing instruction. *Preventing School Failure*, *64*(1). https://doi.org/10.1080/1045988X.2019.1627999

Yang, D. C., & Sianturi, I. A. J. (2022). Analysis of algebraic problems intended for elementary graders in Finland, Indonesia, Malaysia, Singapore, and Taiwan. *Educational Studies*, *48*(1). https://doi.org/10.1080/03055698.2020.1740977

Yarmohammadian, A. (2014). The Relationship between Spatial Awareness and Mathematic Disorders in Elementary School Students with Learning Mathematic Disorder. *Psychology and Behavioral Sciences*, *3*(1). https://doi.org/10.11648/j.pbs.20140301.16

Yuanita, P., Zulnaidi, H., & Zakaria, E. (2018). The effectiveness of Realistic Mathematics Education approach: The role of mathematical representation as mediator between mathematical belief and problem solving. *PLoS ONE*, *13*(9). https://doi.org/10.1371/journal.pone.0204847

Yustinaningrum, B., & Lubis, N. A. (2019, June). Implementasi conceptual change teaching dalam mereduksi miskonsepsi mahasiswa materi induksi matematika. In *Prosiding Seminar Nasional Matematika Dan Pendidikan Matematika* (Vol. 2, No. 1, pp. 39-49).

AUTHOR'S BIOGRAPHY

Dr. Mohamad Salam, S.Pd, M.Si.

Born in Raha, 17 April 1969. Teaching staff at Halu Oleo University. Bachelor of Mathematics Education at Halu Oleo University, Kendari, graduated in 1994; Master of Mathematics Bandung Institute of Technology, Bandung, graduated in 2000; and S3 Education Technology, Jakarta State University, Jakarta, graduated in 2019.