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Students' Mathematical Abstraction Thinking Ability with Kinesthetic Learning Style through Multi Representation Discourse Learning Model Assisted by Performance Assessment Integrated with Google Sites

Sindi Nur Aini[1*], Stevanus Budi Waluya[1], Ardhi Prabowo[1], Arief Agoestanto[1], Masrukan[1], Agnita Siska Pramasdyahsari[2], Ebenezer Bonyah[3]
[1]Department of Mathematics Education, Semarang State University, Semarang, Indonesia
[2]Department of Mathematics Education, University of PGRI Semarang, Semarang, Indonesia
[3]Department of Mathematics Education, Akenten Appiah Menka University of Skills Training and Entrepreneurial Development, Kumasi, Ghana
*sindinuraini14@students.unnes.ac.id

ABSTRACT

This study aims to describe the mathematical abstraction ability of kinesthetic learners through the application of a Multi-Representation Discourse (MRD) learning model assisted by performance assessment and integrated with Google Sites. This research employed a qualitative descriptive design. The participants were two 11th-grade students at SMA Negeri 11 Semarang identified as having a kinesthetic learning style, selected using purposive sampling. Data were collected through abstraction ability tests and interviews, followed by technique triangulation to ensure validity. The analysis involved data reduction, display, verification, and conclusion drawing. The triangulation of test and interview data revealed that kinesthetic learners demonstrated fairly capable to capable performance across several indicators of mathematical abstraction, particularly in representing ideas, manipulating abstract objects, and connecting mathematical processes. However, they showed difficulties in visualizing complex spatial contexts and selecting appropriate strategies. Improvements in abstraction ability were observed after the implementation of the MRD model with performance assessment support. This study integrates performance-based assessment within the MRD model using Google Sites to support kinesthetic learners' abstract reasoning in mathematics. The results of this study can benefit educators and curriculum designers in developing instructional models tailored to students with kinesthetic learning preferences, especially in fostering mathematical abstraction skills.

Keywords: mathematical abstraction, kinesthetic learning style, multi-representation discourse, performance assessment, Google Sites

INTRODUCTION

Mathematics is one of the most important disciplines, as it plays a crucial role not only in daily life but also as a foundation for various fields of science [1]. However, mathematics learning is often perceived negatively by students due to difficulties in processes such as reasoning, problem-solving, and proving areas that cannot be directly transferred since mathematics deals with abstract subjects[1–7]. Students show diverse responses when faced with math problems some solve them easily, others want to try but are unsure how, and some choose to ignore the questions altogether [8]. The learning challenge becomes even greater when instruction relies solely on memorization, making it essential to use engaging methods that help students construct ideas[9]. In this context, the process of mathematical abstraction defined as the mental construction of experiences based on prior knowledges is key to understanding mathematical concepts [10]. According to the theory of didactical situations, this abstraction occurs in the formulation phase, which is the initial stage where knowledge is acquired through experience [11]. The goal of mathematics instruction is to gradually guide students from concrete manipulation to abstract thinking in problem-solving, as mathematics education emphasizes students' active involvement in constructing their own knowledge . Therefore, the ability to think abstractly is a crucial aspect that students must develop [1,6,12–14].

The ability of mathematical abstraction in Indonesia remains relatively low, ranging from elementary school to higher education levels [6,13–16], a condition also observed in South Korea, where efforts to improve this ability are still ongoing [17]. The low level of this ability is reflected in students' difficulties in manipulating mathematical concepts, understanding relationships between concepts, making generalizations and equations according to context, as well as connecting concepts to real-life situations [18]; [18]; [19]; [20]. A similar condition was also found among 11th-grade students at SMA Negeri 11 Semarang, as shown by the results of an abstraction ability test on prerequisite material related to angle relationships, such as right-angled triangles, altitudes, and similarity.

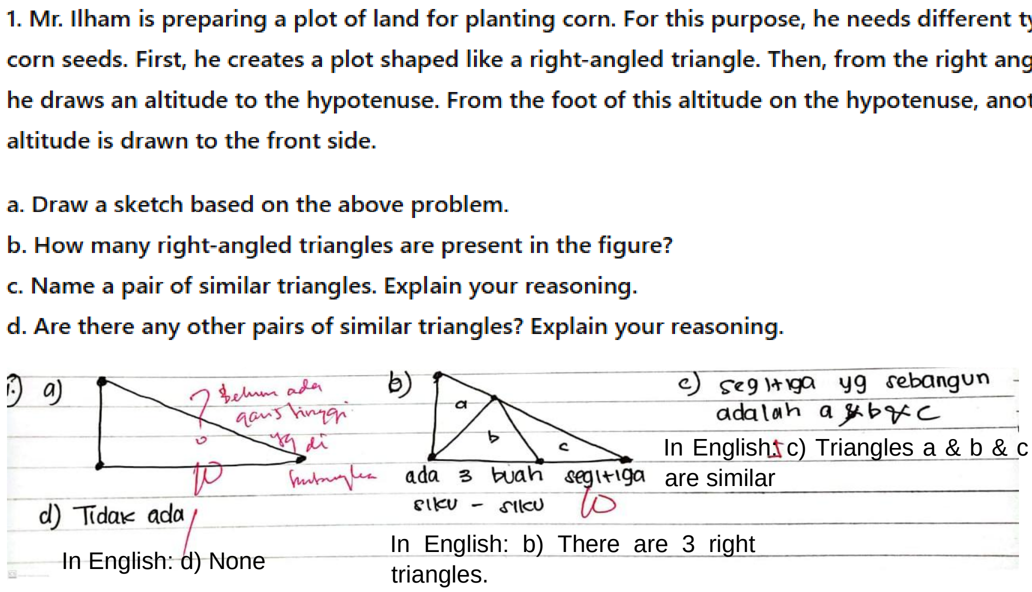


Figure 1. shows a sample of students' work

The limited abstraction ability of eleventh-grade students at SMA Negeri 11 Semarang can also be observed through their problem-solving approach, as shown in Figure 1 below. Many students still struggle to sketch the problems as requested, which falls under the indicator of identifying the characteristics of manipulated or imagined objects. This can be seen in the following student response, which incorrectly sketches a new right-angled triangle formed by drawing an altitude from the right angle to the hypotenuse, as it lacks the right-angle symbol on the indicated side. As a result, the student was unable to answer the second question, which asked how many right-angled triangles were formed. This also indicates that the indicator of applying concepts in appropriate contexts was not fulfilled, as seen from the student’s lack of mastery of the concept of an altitude.

Students’ low mathematical abstraction ability is attributed to unsystematic problem-solving habits, insufficient concept-based reasoning, a tendency to respond with immediate numerical answers, and a lack of structured argumentation when explaining mathematical ideas [21]; [22];[20]. Additionally, the demand for symbolic and imaginative thinking in problem-solving poses a significant challenge [23]. Interview results revealed that students struggle due to unfamiliarity with sketching problems and limited conceptual understanding, as the material was taught long ago. This supports [24] finding that conceptual comprehension is a key obstacle to abstract thinking.

Recent studies have shown increasing interest in students' abstraction ability in mathematics, particularly in relation to learning styles [25–29]. Learning styles affect abstraction by influencing how students process information to generalize, analyze, and infer abstract concepts. [30] further emphasized that compatibility between students' learning styles and cognitive abilities positively impacts academic performance.

Learning style refers to the unique and consistent way in which students absorb and process information [31]. Piaget's Theory of Cognitive Development states that learning styles which support exploration and reflection can accelerate the development of abstract thinking. According to Piaget's cognitive development theory, the ability to think abstractly develops through active exploration of the environment and reflection on one's experiences. This is supported by [32], who explain that Piaget emphasized the importance of learners being actively engaged in exploring their surroundings and reflecting on their experiences to foster the development of abstract thinking. Such abstraction facilitates the transition toward the formal operational stage. In the context of modern learning, students' learning styles such as visual, auditory, and kinesthetic (VAK) can play a significant role in supporting the processes of exploration and reflection. According to educational research on embodied cognition and learning styles, mathematical abstraction enables students to reason beyond concrete objects and engage with ideas symbolically and logically [33]; [34]. However, kinesthetic learners who process information best through movement and physical experience often find abstract symbolic reasoning (e.g. working with numbers and mathematical symbols) difficult unless instruction is embedded in interactive and concrete activities. This demonstrates that effective abstraction can be achieved when such learners engage bodily in experiential learning contexts.

This study investigates how the application of the MRD model, supported by performance assessment and digital integration via Google Sites, impacts kinesthetic students' mathematical abstraction abilities.

LITERATURE REVIEW

1. Mathematical Abstraction Ability

Mathematical abstraction ability refers to the capacity to represent situations in mathematical problems [19]. According to [35] abstraction thinking is the ability to discover various ways to solve a problem without the actual presence of the object, and to think symbolically and imaginatively to find solutions to abstract mathematical problems. Furthermore, [36] state that abstraction ability also enables students to construct new mathematical concepts using prior knowledge they already possess. Based on these perspectives, it can be synthesized that mathematical abstraction ability is the students' capability to represent situations required to solve mathematical problems without involving the physical presence of the object by visualizing the object in symbolic, graphical, or diagrammatic forms and to identify patterns and relationships among mathematical concepts [35]; [19]; [36].

2. Kinesthetic Learning Style

[37] defined learning style as a set of distinctive characteristics that describe how individuals learn, covering cognitive, affective, and physiological aspects. [38] added that learning style refers to the way students take responsibility for learning in the manner most appropriate to their abilities and needs. According to [39], one type of learning style is the kinesthetic learning style. This style refers to individuals who tend to understand and remember information more effectively through physical activities such as movement, direct action, and tactile experiences related to the content being learned [40]. Stated that kinesthetic learners tend to learn through physical movement and direct experience. Their characteristics include

difficulty recalling visual information without concrete experience, a preference for memorizing while moving, inability to sit still for long periods, and a tendency to use their bodies in the learning process, such as pointing while reading. They are typically physically active, action-oriented, and often have less tidy handwriting.

3. Multi-Representation Discourse

[41] defined the Multi-Representation Discourse (MRD) learning model as one that strongly emphasizes learning within diverse groups, allowing members to support each other, collaborate to overcome challenges, and integrate various perspectives to achieve the best outcomes for both the group and individuals. The MRD learning model is a type of cooperative learning in which the learning process is conducted in small groups [42]. The instructional steps or syntax of the MRD model used in this study refer to [43], consisting of: preparation, introduction, development, application, and closing.

4. Performance Assessment

[44] and [45] similarly defined assessment as a systematic and continuous process of collecting and evaluating data to guide and enhance student learning, with one form being performance assessment, also known as authentic assessment. One type of assessment is performance assessment, also known as authentic assessment. The term "authentic" implies being original, genuine, valid, or consistent (reliable).[46] defined performance assessment as a form of evaluation that focuses on two main tasks: evaluating students' performance through their products or creative outcomes, and observing the process as the skills are performed. [44] emphasized that the essence of performance assessment is a procedure for collecting diverse data that provides an overall picture of how students learn and develop.

METHODOLOGY

This study is descriptive research employing a qualitative approach, aimed at portraying the mathematical abstraction ability of students with a kinesthetic learning style. The subjects of the study were 11th-grade students at SMA Negeri 11 Semarang who were identified as having dominant characteristics of kinesthetic learners through a learning style questionnaire. From ten students identified as kinesthetic learners, two were selected as research participants using purposive sampling. The selection was based on their highest kinesthetic scores, strong communication skills, willingness to participate fully, and active involvement in classroom activities. This choice was also in line with the nature of qualitative case study research, which prioritizes depth of analysis rather than generalization.

The data collection instruments consisted of a mathematical abstraction test, interview guidelines, and observation sheets. These instruments were validated through expert judgment by two lecturers in mathematics education and were pilot-tested with students outside the research sample to ensure clarity and feasibility. Data collection procedures involved administering the test and conducting in-depth interviews, complemented by technique triangulation (tests, interviews, and observations) to enhance data validity.The data analysis was carried out through the stages of data reduction, data display, verification, and conclusion drawing.

The instrument used in this research was a set of problem-based tasks designed by the researcher to measure the mathematical abstraction ability of 11thgrade students. These tasks were developed based on indicators proposed by [47], which include: (a) representing mathematical ideas in language and symbols, (b) identifying characteristics of objects that are manipulated or imagined, (c) applying concepts in relevant contexts, (d) making connections between processes or concepts to form understanding, and (e) manipulating abstract mathematical objects.

RESULTS

In this study, students' mathematical abstraction ability was analyzed by comparing the data obtained from the abstraction ability test with findings from interviews conducted with the research subjects, namely students with a kinesthetic learning style. The interviews served as a triangulation method to confirm and strengthen students' responses based on indicators of mathematical abstraction ability. Prior to the implementation of the study, a learning style questionnaire was administered to identify each student's learning preferences. Based on the analysis of the questionnaire, out of 31 student respondents, 10 students (32%) were identified as having a kinesthetic learning tendency. This finding indicates that a portion of the students preferred learning through physical activities, bodily movement, and tended to experience difficulty remaining still for extended periods.

To gain a more comprehensive understanding of students' mathematical abstraction ability in the context of related angles, the following section provides an in-depth description of the responses given by kinesthetic learners to the abstraction ability test presented in Figure 2

1. Ilham wants to determine the height of a two-story multipurpose building at his school without directly measuring it.

Given that the distance between Ilham and the building is 10 meters, the angle of elevation is 35°, and the height from Ilham's eyes to the ground is 1.76 meters (with sin 55° = 0.8 and tan 55° = 1.4):

a. Draw a sketch to represent the situation described above.

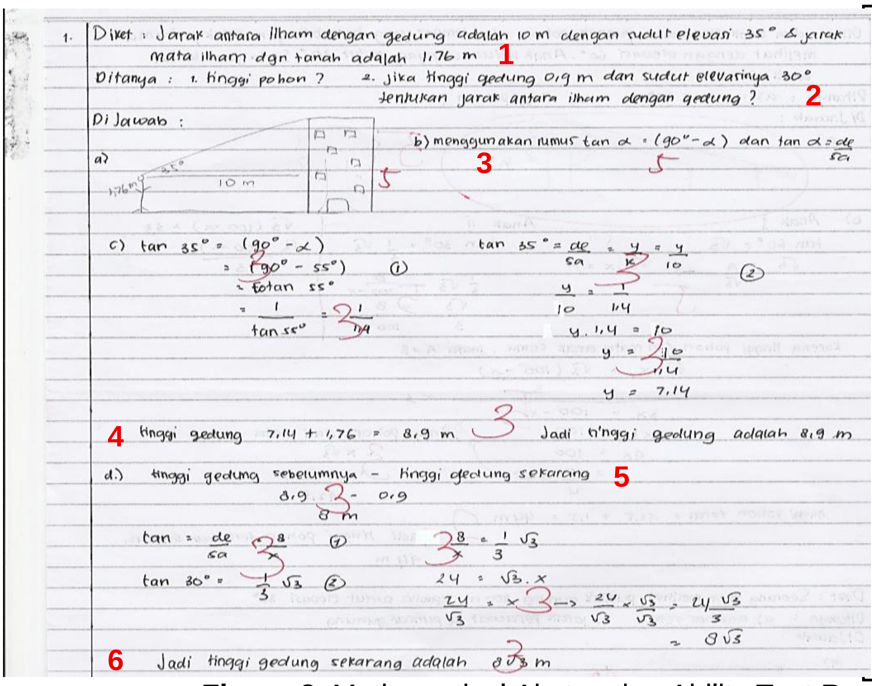
b. What steps should Ilham take to determine the height of the building without directly measuring it?

c. Explain the method used to calculate the height of the building.

d. If the situation is reversed, and the height of the new building is 0.9 meters shorter than the previously calculated height, and the angle of elevation between Ilham and the building is 30°, determine the distance between Ilham and the building.

Figure 2. Mathematical Abstraction Ability Test Item

The following is the result of the subject's mathematical abstraction ability test, as presented in Figure 3 below.



In English:

1) Given: the distance between Ilham and the building is 10 meters with an angle of elevation of 35°, and the distance from Ilham's eyes to the ground is 1.76 meters
2) Asked:
1.What is the height of the building?
2.If the building is 0.9 meters shorter and the angle of elevation is 30°, determine the distance between Ilham and the building."
3) Using the tangent formula $\tan\alpha = (90° - x)$ and tangent x = $\frac{de}{sa}$, de = depan = opposite side, sa= samping = adjacent side
4) The height of the building is 7.14 + 1.76 = 8.9. Therefore, the height of the building is 8.9 meters
5) previous building height - current building height
6) Therefore, the current height of the building is 8√3

Figure 3. Mathematical Abstraction Ability Test Results of Subject S-01

Subject demonstrated the ability to visualize a narrative problem and translate it into a detailed and contextually accurate sketch (item 1a). In item 1b, the subject was able to select and apply the appropriate trigonometric formula (tangent) to solve the problem. In item 1c, the subject carried out the calculations procedurally to determine the building's height, although there were inconsistencies in the use of significant figures. In item 1d, the subject attempted a new strategy but made an error in selecting the correct trigonometric function, though they still showed an understanding of mathematical structure and problem-solving procedures. Overall, the subject showed adequate ability in connecting mathematical concepts and manipulating abstract objects, although improvement is needed in accuracy and conceptual selection.

The interview results with the subject indicate that they were able to answer questions fluently and explain the problem-solving process in a structured manner. The subject understood most of the problem context, although some inaccuracies were found in terms of precision and problem-solving strategy, such as errors in sketching and the inappropriate use of trigonometric concepts. The subject stated that they could imagine the problem situation, although they needed time to visualize it, which demonstrates their ability to identify the characteristics of objects and represent mathematical ideas—though their abstract visualization was not yet optimal.

The subject was also able to explain the steps of the solution logically based on the available information, although they still made errors in selecting the appropriate mathematical concept for certain problems, such as using an incorrect trigonometric function. Nevertheless, the subject showed the ability to identify known and unknown information and to sequence solution steps consistently by connecting various concepts. This indicates that the subject was capable of constructing relationships between processes and manipulating abstract mathematical objects through the use of symbols, variables, and equations.

Tabel 1. Results of Technique Triangulation

No.	Indicator of Mathematical Abstraction Ability	Test Result	Interview Result	Triangulation Conclusion
1	Identifying characteristics of objects that are manipulated or imagined	Fairly Capable	The subject stated they could imagine the problem, but admitted to perceptual errors, especially in question number 2	Consistent – Fairly capable, but experienced difficulty in accurately visualizing spatial context
2	Representing mathematical ideas in language and symbols	Fairly Capable	The subject was able to express ideas using symbols and drawings but acknowledged limitations in sketch completeness and labeling	Consistent – Fairly capable, although more precision and completeness in visual representation are needed
3	Applying concepts in appropriate contexts	Fairly Capable	The subject explained their reasoning for concept selection but was inaccurate in choosing the correct formula for question number 3	Consistent – Fairly capable, needs improvement in understanding complex contexts and problem-solving strategies

No.	Indicator of Mathematical Abstraction Ability	Test Result	Interview Result	Triangulation Conclusion
4	Making connections between processes or concepts to construct understanding	Capable	The subject demonstrated logical thinking and mentioned concept relationships (e.g., between tangent and angle information), though not in depth	Consistent – Capable of constructing connections between processes, though explanations were not fully detailed
5	Manipulating abstract mathematical objects	Capable	The subject showed understanding in transforming problems into mathematical forms and was able to use variables and construct equations	Consistent – Capable of abstract thinking and manipulating mathematical objects through symbols and procedures effectively

The triangulation results between the test and interview indicate that subject S-06 falls into the category of fairly capable to capable in most indicators of mathematical abstraction ability, with consistent results across both instruments. The subject was able to imagine simple mathematical situations but had difficulty visualizing more complex problems, indicating a need for improvement in spatial understanding and problem interpretation.

In representing mathematical ideas, the subject was fairly capable of using sketches and symbols, although there were inaccuracies in visual representation and a lack of detail that could affect problem-solving strategies. Regarding the application of concepts, the subject was able to explain their chosen strategies but made errors in selecting the appropriate trigonometric concept due to misinterpretation of the problem context.

The subject also demonstrated the ability to logically connect information into a coherent solution, though not always in detail. In manipulating abstract mathematical objects, the subject showed relatively good mastery in using symbols and variables accurately. Overall, the subject demonstrated solid mathematical abstraction skills, though reinforcement is needed in contextual visualization and strategy accuracy.

DISCUSSION

Kinesthetic learners possess a fairly optimal level of mathematical abstraction ability. This is evident from the results of the abstraction ability test and interviews, which show that students with a kinesthetic learning style are generally capable of visualizing problems, although they still face some difficulties when the problems become too complex. Kinesthetic learners tend to be able to transform mathematical representations from one form to another, such as images, symbols, and so on. They are fairly capable in the indicator of applying concepts in appropriate mathematical contexts; however, misinterpretation of the problem and challenges in visualizing the context sometimes lead to incorrect strategy selection.

In terms of the indicator of establishing connections between processes or concepts to construct understanding, students show moderate ability but still encounter issues related to inaccuracy, resulting in errors categorized as inappropriate data, which refers to mistakes in inputting data used in calculations. This aligns with the findings of [48], who stated that kinesthetic learners tend to have a lower level of accuracy during calculations.

Kinesthetic learners are capable of processing, transforming, and working with abstract mathematical objects and can use logical reasoning to draw conclusions or make inferences based on manipulations they perform. They are also able to explain the steps used to arrive at a solution in detail. This is supported by research conducted by [49], which found that kinesthetic learners have the ability to explain the problem-solving stages along with the results and to provide arguments supporting those steps. According to Piaget's theory of cognitive development, learning styles that support exploration and reflection such as the kinesthetic learning style can accelerate the development of abstract thinking.

Kinesthetic learners demonstrate a good ability to imagine mathematical problems, even though some of their sketches are imprecise. Based on test and interview results, their ability to imagine problems is better than that of auditory learners. This is supported by findings from [50], which state that several kinesthetic learners also demonstrated visual representation skills, as indicated by their use of drawings as a strategy for solving problems. However, the visual representations were not always fully accurate or aligned with the given problem, though more dominant than those of auditory learners, who tend to excel in verbal representation.

Kinesthetic learners showed improvement in their abstraction ability after engaging in learning using the Multi-Representation Discourse Model. This improvement was reflected in the increase in their posttest scores compared to their pretest scores. Initially, kinesthetic learners struggled to imagine problems, had difficulty determining the appropriate concepts to use, and were unable to complete most of the test items. Limited mathematical representation led to insufficient understanding of the material, which in turn caused difficulties in solving the problems presented [51]. However, after receiving instruction through the Multi-Representation Discourse Model supported by performance assessment, these students were able to complete all posttest items. While their performance was not yet optimal, improvements were evident, particularly in their ability to sketch the problems posed. Thus, the implementation of the Multi-Representation Discourse Model with performance assessment support is a contributing factor to the observed changes in students' mathematical abstraction ability.

CONCLUSION

The findings of this study indicate that students with a kinesthetic learning style possess mathematical abstraction abilities at a level ranging from fairly capable to capable across most indicators. While they show strengths in manipulating abstract mathematical objects, making logical connections, and representing ideas through sketches and symbols, challenges remain in visualizing complex spatial contexts and selecting appropriate problem-solving strategies. The application of the Multi-Representation Discourse learning model, supported by performance assessment and integrated with Google Sites, contributed to an observable improvement in students' abstraction abilities. This suggests that instructional approaches that align with kinesthetic learners' characteristics particularly those involving physical engagement and visual representations can enhance their capacity to think abstractly in mathematics.

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REFERENCES

[1] Nisa AL. Analisis Kemampuan Abstraksi Matematis Siswa Dalam Menyelesaikan Soal Pada Materi Segiempat Kelas Vii Smp. JPM : Jurnal Pendidikan Matematika 2019;4:01. https://doi.org/10.33474/jpm.v4i1.2610.

[2] Arafah AA, Sukriadi S, Samsuddin AF. Implikasi Teori Belajar Konstruktivisme pada Pembelajaran Matematika. Jurnal Pendidikan Mipa 2023;13:358–66. https://doi.org/10.37630/jpm.v13i2.946.

[3] Kamil MR, Imami AI, Abadi agung P. Analisis Kemampuan Berpikir Komputasional Matematis Siswa Kelas IX SMP Negeri 1 Cikampek Pada Materi Pola Bilangan. AKSIOMA: Jurnal Matematika Dan Pendidikan Matemnatika 2021;12:259–70.

[4] Komala E. Analysis of Students' Mathematical Abstraction Ability By Using Discursive Approach Integrated Peer Instruction of Structure Algebra Ii. Infinity Journal 2018;7:25. https://doi.org/10.22460/infinity.v7i1.p25-34.

[5] Mawadah Putri Islamiati. Studi Kasus Kemampuan Abstraksi Matematis Siswa Kelas XII Pada Materi Dimensi Tiga. Didactical Mathematics 2022;4:127–37. https://doi.org/10.31949/dm.v4i1.2076.

[6] Nurrahmah A, Kartono K, Zaenuri Z, Isnarto I. Tinjauan Pustaka Sistematis : Abstraksi Matematis Mahasiswa pada Pembelajaran Matematika Berdasarkan Teori APOS. Prosiding Seminar Nasional Pascasarjana Universitas Negeri Semarang 2022:120–9.

[7] Sumekar W, Nurhasanah F, Sutopo S. Analyzing students' abstraction in learning common tangent lines of two circles based on cognitive styles. Beta: Jurnal Tadris Matematika 2019;12:94–108. https://doi.org/10.20414/betajtm.v12i2.325.

[8] Setiyani, Waluya SB, Sukestiyarno YL, Cahyono AN. Construction of reflective thinking: A field independent student in numerical problems. Journal on Mathematics Education 2024;15:151–72. https://doi.org/10.22342/jme.v15i1.pp151-172.

[9] Khasanah N, Nurkaidah N, Dewi R, Prihandika YA. The Process of Student's Mathematic Abstract from Spatial Intelligence. Journal of Mathematics and Mathematics Education 2019;9:24. https://doi.org/10.20961/jmme.v9i2.48396.

[10] Khasanah SU, Setiawan B. PENERAPAN PENDEKATAN SOCIO-SCIENTIFIC ISSUES BERBANTUAN E-LKPD PADA MATERI ZAT ADITIF UNTUK MENINGKATKAN LITERASI SAINS SISWA 2022;10:313–9.

[11] Prabowo A, Suryadi D, Dasari D, Juandi D, Junaedi I. Learning Obstacles in the Making of Lesson Plans by Prospective Mathematics Teacher Students. Educ Res Int 2022;2022. https://doi.org/10.1155/2022/2896860.

[12] Islam SN, Susilawati W, Sugilar H. Analisis Kesalahan Siswa Dalam Menyelesaikan Soal Berpikir Abstraksi Matematis Berdasarkan Kriteria Watson. Jurnal Perspektif 2021;5:112. https://doi.org/10.15575/jp.v5i1.135.

[13] Putra JD, Suryadi D, Juandi D. Mathematical abstraction ability of prospective math teacher students. J Phys Conf Ser 2018;1132. https://doi.org/10.1088/1742-6596/1132/1/012049.

[14] Sugandi AI, Linda L, Bernard M. Pengembangan Bahan Ajar Berbantuan Media Tubomatika Untuk Meningkatkan Kemampuan Abstraksi Matematis Siswa. AKSIOMA: Jurnal Program Studi Pendidikan Matematika 2020;9:809. https://doi.org/10.24127/ajpm.v9i3.2918.

[15] Nihayah AD. Analisis Kemampuan Berpikir Abstrak Siswa SMA 2021;8:299–303.

[16] Yusepa B. Kemampuan Abstraksi Matematis Siswa Sekolah Menengah Pertama (Smp) Kls Viii. Symmetry: Pasundan Journal of Research in Mathematics Learning and Education 2017;I. https://doi.org/10.23969/symmetry.v1i1.233.

[17] Hong JY, Kim MK. Mathematical Abstraction in the Solving of Ill-Structured Problems by Elementary School Students in Korea 2016;12:267–81. https://doi.org/10.12973/eurasia.2016.1204a.
[18] Fitriani D, Suryana Y, Hamdu G. Pengembangan Instrumen Tes Higher-Order Thinking Skill pada Pembelajaran Tematik Berbasis Outdoor Learning di Sekolah Dasar Kelas IV. Indonesian Journal of Primary Education 2018;2:87. https://doi.org/10.17509/ijpe.v2i1.13752.
[19] Nihayah AD. ANALISIS KEMAMPUAN BERPIKIR ABSTRAK SISWA SMA DALAM MATERI GEOMETRI. vol. 8. n.d.
[20] Yusepa B. KEMAMPUAN ABSTRAKSI MATEMATIS SISWA SEKOLAH MENENGAH PERTAMA (SMP) KLS VIII. Symmetry: Pasundan Journal of Research in Mathematics Learning and Education 2017. https://doi.org/10.23969/symmetry.v1i1.233.
[21] Khasanah N, Nurkaidah N, Dewi R, Prihandika YA. The Process of Student’s Mathematic Abstract from Spatial Intelligence. Journal of Mathematics and Mathematics Education 2019;9:24. https://doi.org/10.20961/jmme.v9i2.48396.
[22] Putra JD, Suryadi D, Juandi D. Mathematical abstraction ability of prospective math teacher students. J Phys Conf Ser 2018;1132:012049. https://doi.org/10.1088/1742-6596/1132/1/012049.
[23] Hong JY, Kim MK. Mathematical Abstraction in the Solving of Ill-Structured Problems by Elementary School Students in Korea. EURASIA Journal of Mathematics, Science and Technology Education 2016;12. https://doi.org/10.12973/eurasia.2016.1204a.
[24] Nurhikmayati I. Kesulitan Berpikir Abstrak Matematika Siswa Dalam Pembelajaran Problem Posing Berkelompok. Kalamatika: Jurnal Pendidikan Matematika 2017;2:159–76. https://doi.org/10.22236/kalamatika.vol2no2.2017pp159-176.
[25] Faizah DN. Analisis Kemampuan Abstraksi Matematis Siswa SMA Kelas X Ditinjau dari Gaya Belajar. Universitas Muhammadiyah Purwokerto, 2016.
[26] Fajriah N, Susanah. Profil Kemampuan Abstraksi Reflektif Siswa dalam Menyelesaikan Masalah Geometri ditinjau dari Gaya Belajar. Jurnal Ilmiah Pendidikan Mate 2022;11.
[27] Natonis SFM, Daniel F, Gella NJM. Analisis Representasi Matematis Siswa Ditinjau dari Gaya Belajar 2022;4:3025–33.
[28] Nurrahmah A, Rochmad, Isnarto. Kemampuan Berpikir Abstraksi Matematis Mahasiswa pada Mata Kuliah Statistika Matematika ditinjau dari Gaya Belajar. PRISMA, Prosiding Seminar Nasional Matematika, vol. 4, Semarang: 2021, p. 67–74.
[29] Rosmiati U, Ratnaningsih N. Analysis of mathematical abstraction ability in terms of learning style kolb assisted by google slides media. Jurnal Math Educator Nusantara 2021;7:26–36.
[30] Ucu Rosmiati, Ratnaningsih N, Ni’mah K. Analisis Kemampuan Abstraksi Matematis Ditinjau dari Gaya Belajar Kolb Berbantuan Media Google Slides. Jurnal Math Educator Nusantara: Wahana Publikasi Karya Tulis Ilmiah Di Bidang Pendidikan Matematika 2021;7:26–36. https://doi.org/10.29407/jmen.v7i1.15675.
[31] Purwanto WR, Waluya SB, Rochmad, Wardono. Analysis of mathematical critical thinking ability in student learning style. J Phys Conf Ser 2020;1511. https://doi.org/10.1088/1742-6596/1511/1/012057.
[32] Cerovac M, Keane T. Early insights into Piaget’s cognitive development model through the lens of the Technologies curriculum. Int J Technol Des Educ 2024;35:61–81. https://doi.org/10.1007/s10798-024-09906-5.
[33] Lehavot K, Litz B, Millard SP, Hamilton AB, Sadler A, Simpson T. Study adaptation, design, and methods of a web-based PTSD intervention for women Veterans. Contemp Clin Trials 2017;53:68–79. https://doi.org/10.1016/j.cct.2016.12.002.

[34] Beilock SL, Goldin-Meadow S. Gesture Changes Thought by Grounding It in Action. Psychol Sci 2010;21:1605–10. https://doi.org/10.1177/0956797610385353.
[35] Budiarto MT. Proses Abstraksi Siswa SMP Kelas 1 dalam Mengkonstruksi Kubus dari Rangkaian 6 Persegi. Seminar Nasional Penelitian, Pendidikan Dan Penerapan MIPA 2005 2005:29–39.
[36] Nurhasanah F, Kusumah YS, Sabandar J. Concept of Triangle : Examples of Mathematical. International Journal on Emerging Mathematics Education 2017;1:53–70.
[37] Keefe JW. Learning style: An overview. NASSP's Student Learning Styles: Diagnosing and Proscribing Programs. National Association of Secondary School Principals; 1979.
[38] Wassahua S. Analisis Gaya Belajar Siswa Terhadap Hasil Belajar Matematika Pada Materi Himpunan Siswa Kelas Vii SMP Negeri Karang Jaya Kecamatan Namlea Kabupaten Buru. Jurnal Matematika Dan Pembelajarannya 2016;2:84–104.
[39] Porter B De. Quantum Learning: Unleashing the Genius inYou. New York: Dell Publishing; 1992.
[40] Wahyuni DA. Pengembangan Bahan Ajar Pembelajaran Matematika Berbasis Multimedia pada Materi Peluang untuk Siswa Kelas XI. 2017.
[41] Suyatno. Menjelajah Pembelajaran Inovatif. Jawa Timur: Masmedia Buana Pustaka; 2009.
[42] Rostika D, Junita H. Sd Dalam Pembelajaran Matematika Dengan Model Diskursus Multy Representation (Dmr). Jurnal Pendidikan Dasar 2017;9:35–46.
[43] Afni NS. Pengaruh Model Pembelajaran Diskursus Multi Representasi (DMR) terhadap Kemampuan Eksplorasi Siswa SMP Negeri 4 Sumbang. Universitas Muhammadiyah Purwokerto, 2018.
[44] Masrukan. Asasmen Otentik Pembelajaran Matematika. Semarang: Fakultas Matematika dan Ilmu Pengetahuan Alam Universitas Negeri Semarang; 2017.
[45] Yuniati S. ASESMEN KINERJA (PERFORMANCE ASSESSMENT) DALAM PEMBELAJARAN MATEMATIKA. 2011.
[46] Kartono. Hands On Activity Pada Pembelajaran Geometri Sekolah Sebagai Asesmen Kinerja Siswa. Jurnal Matematika Kreatif-Inovatif 2010;1:21–32.
[47] Mukhtar. Peningkatan Kemampuan Abstraksi Dan Generalisasi Matematis Siswa Sekolah Menengah Pertama Melalui Pembelajaran Dengan Pendekatan Metaphorical Thinking. Univeristas Pendidikan Indonesia, 2013.
[48] Jaenudin, Nindiasari H, Pamungkas AS. Analisis Kemampuan Berpikir Reflektif Matematis Siswa ditinjau dari Gaya Belajar 2017;1.
[49] Puspitasari ND, Susanah S. Analisis Representasi Matematis Siswa SMP dalam Memecahkan Masalah Aritmatika Sosial. MATHEdunesa 2022;11:958–67. https://doi.org/10.26740/mathedunesa.v11n3.p958-967.
[50] Natonis SFM, Daniel F, Gella NJM. Analisis Representasi Matematis Siswa Ditinjau dari Gaya Belajar. EDUKATIF : JURNAL ILMU PENDIDIKAN 2022;4:3025–33. https://doi.org/10.31004/edukatif.v4i2.2592.
[51] Hanifah, Waluya SB, Isnarto, Asikin M, Rochmad. Analysis mathematical representation ability by self-efficacy of prospective mathematics teachers. J Phys Conf Ser 2021;1918. https://doi.org/10.1088/1742-6596/1918/4/042118.