Temperament and Mathematical Representation: A Psychological Study on Students' Mathematical Problem Solving

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Abstract

This study aims to examine the differences in students' mathematical representation abilities in solving mathematical problems based on variations in temperament. A quantitative comparative approach was employed using an independent sample t-test design to compare two groups of students with sanguine and melancholic temperaments. The research instruments included a mathematical representation ability test and a temperament questionnaire based on the classical temperament classification. Statistical analysis revealed a significant difference between the two groups, indicating that students with a melancholic temperament demonstrated higher and more systematic representational abilities than those with a sanguine temperament. These findings suggest that temperament, as an internal psychological factor, influences students' thinking styles and representational skills in mathematical problem-solving. The implications of this study emphasize the importance of developing instructional strategies that are responsive to individual learner characteristics, making mathematics learning more adaptive and effective.

Keywords

Mathematical Representation, Problem Solving, Temperament

Introduction

Recent reforms in mathematics education have emphasized a fundamental shift from an exclusive focus on procedural fluency and computational accuracy toward the development of higher-order thinking, reasoning, and problem-solving skills. Mathematical problem solving is increasingly understood as a complex cognitive activity that requires learners to analyze situations, construct strategies, and justify solutions rather than merely produce correct numerical answers. Within this paradigm, students are expected to engage in meaningful sense-making processes that involve organizing information, recognizing relationships, and communicating ideas coherently. Consequently, contemporary mathematics education places strong emphasis on competencies that support these processes, particularly the ability to represent mathematical ideas in multiple forms.

Mathematical representation has been widely acknowledged as a core component of mathematical proficiency. According to the National Council of Teachers of Mathematics, mathematical power encompasses students' abilities to explore, conjecture, reason logically,

solve non-routine problems, and communicate and connect mathematical ideas effectively (NCTM, 2018). Representation defined as the expression of mathematical ideas through visual, symbolic, verbal, or graphical forms, plays a central role in achieving these aims. By enabling learners to externalize and reorganize their thinking, representations support deeper conceptual understanding and facilitate the transition between concrete experiences and abstract reasoning. As a result, representation is no longer viewed as a supplementary skill but as an essential mechanism for mathematical thinking and problem solving.

Over the past decade, research on multiple representations has expanded substantially. Numerous studies have demonstrated that engaging students in transforming and coordinating different representations enhances conceptual understanding and problem-solving performance. A systematic review by Ruamba et al. (2025), covering studies published between 2014 and 2023, reported that visual and multimodal representations reduce cognitive load and strengthen students' ability to construct mathematical meaning. Similarly, empirical studies have shown that the integration of symbolic, graphical, and verbal representations facilitates conceptual connections and increases learner engagement (Bach et al., 2024; Hankeln & Prediger, 2025). These findings align with the position of the NCTM, which explicitly recognizes representational competence as a fundamental mathematical standard essential for student success (Adleff et al., 2023).

Despite this growing body of evidence, a persistent challenge in mathematics education is that many students continue to struggle with problem solving, particularly when tasks require systematic reasoning and coordination across representations. Difficulties often arise when students fail to translate information from one form to another, such as from verbal descriptions to symbolic equations or from graphs to algebraic expressions. These challenges suggest that effective problem solving is not solely determined by exposure to instructional strategies but also by learners' internal capacities to process, organize, and regulate information.

In response to these challenges, much of the existing research has proposed pedagogical solutions centered on instructional design. Approaches such as Realistic Mathematics Education and Problem-Based Learning have been shown to improve students' representational abilities when multiple representations are explicitly embedded in instruction. For example, Muhtarom et al. (2024) demonstrated that students taught through RME with systematic use of multiple representations achieved higher levels of conceptual understanding and mastery. Similarly, Wahyuni and Mubarok (2024) reported that a Problem-Based Learning model integrating multiple representations significantly enhanced students' problem-solving skills. These studies provide strong evidence that instructional interventions can effectively support representational competence.

However, instructional approaches alone do not fully account for the variability observed in students' representational performance. Even within the same learning environment, students often exhibit markedly different ways of interpreting problems, organizing solution steps, and expressing mathematical ideas. This observation has led researchers to consider internal learner characteristics as an additional explanatory dimension. Cognitive factors such as working memory, executive function, and self-regulation have been shown to influence mathematical performance (Blair et al., 2015; Wang et al., 2015). More recently, psychological factors—including motivation, self-efficacy, and emotional regulation—have also been recognized as important contributors to problem-solving success (Clem et al., 2020).

Within this broader psychological perspective, temperament represents a particularly relevant yet underexplored factor. Temperament refers to relatively stable individual differences in emotional reactivity, self-regulation, and behavioral tendencies. Prior studies suggest that temperament traits, such as effortful control and emotional responsiveness, can influence students' engagement, persistence, and responses to cognitive challenges (Rawlings et al., 2021; Sánchez-Pérez et al., 2015). From this standpoint, it is plausible that temperament also shapes how students construct and coordinate mathematical representations during problem solving. Nevertheless, quantitative studies examining the relationship between temperament and mathematical representation ability remain scarce.

Although some research has investigated personality or learning styles in relation to mathematical achievement, few studies have explicitly linked temperament to students' use of multiple representations. Existing literature on representation has predominantly focused on cognitive and instructional dimensions, leaving a clear research gap at the intersection of mathematics education and educational psychology. Addressing this gap is essential for developing a more comprehensive understanding of why certain students excel in representational tasks while others struggle, even under similar instructional conditions.

Accordingly, the present study aims to examine students' multiple representation abilities in mathematical problem solving from the perspective of temperament. Specifically, it investigates differences in representational performance among students with different temperament types, with particular attention to how these internal psychological characteristics relate to systematic and accurate problem-solving processes. By integrating insights from mathematics education and temperament theory, this study offers an interdisciplinary contribution that extends existing research beyond instructional design. The findings are expected to provide empirical justification for the hypothesis that temperament influences students' mathematical representation abilities and to inform the development of more responsive and personalized mathematics instruction.

Methodology

This study employed a quantitative comparative research design to examine differences in students' multiple mathematical representation abilities in problem solving based on temperament types. Quantitative comparative research is widely used in mathematics education to systematically identify and analyze differences in specific competencies across predefined groups using statistical procedures (Sugiyono, 2019). This approach is particularly appropriate when the objective is hypothesis testing rather than theory generation, as it allows researchers to determine whether observed differences between groups are statistically significant. In the context of mathematics education, such designs have been extensively applied to compare student performance across demographic, cognitive, or psychological variables, including internal learner characteristics that may influence problem-solving outcomes (Baten & Desoete, 2018; Blair et al., 2015).

The research design adopted in this study was an independent sample t-test. This design was selected to compare the mean scores of two independent groups of students those with sanguine and melancholic temperaments on measures of multiple mathematical representation ability. The independent sample t-test is a robust and commonly used statistical technique in mathematics education research for determining whether two unrelated groups differ significantly on a continuous outcome variable. Previous studies have demonstrated that this test is suitable for analyzing differences in mathematical competencies when group membership is clearly defined and assumptions of normality and homogeneity of variance are satisfied (Sánchez-Pérez et al., 2024; Wang et al., 2015). By employing this design, the study aligns with best practices in quantitative comparative research and ensures methodological rigor.

The population of the study consisted of all tenth-grade students enrolled at SMK Miftahul Ulum Panyeppen Pamekasan during the academic year in which the research was conducted. From this population, a sample of thirty students was selected using purposive sampling. Purposive sampling was chosen to ensure that participants met specific criteria relevant to the research objectives, particularly those related to mathematical competence and temperamental characteristics. The sample was divided into two equal groups: fifteen students identified as having a sanguine temperament and fifteen students identified as having a melancholic temperament. The deliberate focus on these two types of temperament was grounded in psychological theory, as sanguine and melancholic temperaments represent contrasting cognitive and behavioral tendencies, namely spontaneity and communicativeness versus analytical and systematic thinking.

To maintain internal validity and reduce confounding variables, several inclusion criteria were applied in the sampling process. First, participants were required to have mathematics achievement scores above the school average, as determined by a standardized pre-test administered prior to the study. This criterion was intended to control extreme differences

in baseline mathematical ability, which could obscure the influence of temperament on representation skills. Second, each participant was required to demonstrate a dominant temperament type based on the results of a temperament assessment. Third, all students included in the sample provided informed consent and agreed to participate fully in all stages of the research. These criteria are consistent with recommendations in quantitative educational research to ensure comparability between groups and enhance the interpretability of findings (Clem et al., 2020; Rawlings et al., 2021).

Temperament classification in this study was determined using the Personality Temperament Test adapted from Why You Act the Way You Do. This instrument is based on the classical four-temperament theory, categorizing individuals as sanguine, choleric, melancholic, or phlegmatic. Although modern temperament research often employs multidimensional models, classical temperament instruments remain widely used in educational contexts due to their conceptual clarity and practical applicability (Checa et al., 2008; Sánchez-Pérez et al., 2015). The test used in this study consisted of a structured questionnaire designed to identify dominant temperament traits through self-reported behavioral and emotional tendencies. The use of a standardized temperament instrument supports construct validity and aligns with previous studies that have linked temperament traits to academic engagement and cognitive regulation (Blair et al., 2015; Wang et al., 2015).

The primary outcome variable, students' multiple mathematical representation ability, was measured using a mathematical ability test specifically designed for this study. The test consisted of essay-type problem-solving questions that required students to express and coordinate mathematical ideas through verbal explanations, symbolic expressions, visual diagrams, and graphical representations. The design of the test was guided by the representation standards articulated by the National Council of Teachers of Mathematics (NCTM, 2018), which emphasize students' abilities to create, use, and interpret multiple forms of representation as a core mathematical competency. Open-ended items were selected to capture deeper conceptual understanding, and the processes students use to transform information across representations, rather than merely assessing procedural accuracy (Aguilar & Castaneda, 2021; Friesen & Kuntze, 2020).

To ensure content validity, the mathematical representation test was aligned with the tenth-grade curriculum and reviewed by subject-matter experts in mathematics education. The scoring rubric was developed to assess the accuracy, completeness, and coherence of representations across different forms. Reliability was supported through consistent scoring procedures and the use of clearly defined criteria for each representational indicator, which is recommended in assessments involving open-ended responses (Adleff et al., 2023). Such measures are essential to minimize subjectivity and ensure that the instrument reliably reflects students' representational abilities.

Prior to conducting the main statistical analysis, assumption testing was performed to verify the suitability of parametric procedures. Normality of the data distribution for each group was examined using the Shapiro–Wilk test, which is recommended for small sample sizes due to its sensitivity and statistical power (Wang et al., 2015). Homogeneity of variance between the sanguine and melancholic groups was assessed using Levene's test. These procedures are considered essential steps in independent sample t-test analysis, as violations of these assumptions can compromise the validity of statistical conclusions (Sánchez-Pérez et al., 2024).

After confirming that the assumptions of normality and homogeneity were satisfied, data analysis was conducted using SPSS version 23. Descriptive statistics were first computed to summarize the mean scores and standard deviations of mathematical representation ability for each temperament group. These descriptive results are presented in Table 1, which provides an overview of group performance. Subsequently, an independent sample t-test was performed to determine whether the observed differences between the two groups were statistically significant. The significance level was set at 0.05, in accordance with conventional standards in educational research (Priyatno, 2016).

The results of the assumption tests are reported in Table 2 and Table 3, which present the outcomes of the Shapiro–Wilk normality test and Levene's homogeneity test, respectively. The t-test results are summarized in Table 4, displaying the t-value, degrees of freedom, and significance level. Clear presentation of these tables follows best practices in quantitative research, as it allows readers to evaluate the robustness and transparency of the analysis (Baten & Desoete, 2018). Through this systematic methodological approach, the study ensures that conclusions regarding differences in mathematical representation ability based on temperament are grounded in sound statistical and theoretical foundations.

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Results

This study aimed to determine whether there was a significant difference in mathematical representation ability in problem solving between students with sanguine and melancholic temperaments. Data were obtained from the results of mathematical representation tests administered to each group.

Before conducting the independent sample t-test, normality and homogeneity tests were performed on the multiple representation ability scores. Normality testing using the Shapiro-Wilk test is presented in Table 1.

Table 1. Normality Test

Tempramen Group	Sig. (Shapiro-Wilk)
Sanguine	0.211
Melancholic	0.172

Since the significance values for both groups are greater than 0.05, the data are normally distributed. The homogeneity test was conducted using the Levene test to examine the equality of variances between groups, as shown in Table 2.

Table 2. Homogeneity Test

Levene Statistic	Sig.
0.754	0.391

The result shows that the significance value (0.391) is greater than 0.05, indicating that the data have homogeneous variances.

After meeting both assumptions, an independent sample t-test was carried out to determine whether there was a significant difference in mathematical representation ability between the two temperament groups.

Table 3. Descriptive Statistics

Group	n	Mean	Standard Deviation
Sanguine	15	78,13	6,25
Melancholic	15	84,87	5,72

The results of the independent t-test are presented in Table 4.

Table 4. Independent Sample t-Test

t hitung	df	Sig. (2-tailed)
-3.265	28	0.003

Since the significance value (0.003) is less than 0.05, it can be concluded that there is a significant difference between students with sanguine and melancholic temperaments in their mathematical representation abilities. Students with a melancholic temperament tend to have higher and more systematic representation skills compared to those with a sanguine temperament.

Discussions and Conclusions

This study provides empirical evidence that temperament is a meaningful internal psychological factor influencing students' multiple mathematical representation abilities in problem solving. The findings demonstrate a significant difference between students with melancholic and sanguine temperaments, with melancholic students exhibiting more systematic, accurate, and coherent use of multiple representations. These results extend current research on mathematical representation by situating it not only within instructional and cognitive domains but also within the psychological characteristics of learners, thereby offering a more holistic understanding of mathematical problem solving.

The superior representational performance of students with a melancholic temperament can be explained through their characteristic cognitive and behavioural traits. Melancholic individuals are typically described as analytical, reflective, and detail-oriented, qualities that align closely with the demands of mathematical problem solving. Mathematical representation requires learners to interpret problem information carefully, select appropriate representational forms, and coordinate these representations logically. Prior research has consistently shown that analytical and systematic thinking supports effective cognitive processing in mathematics, particularly when tasks involve translating between symbolic, graphical, and verbal forms (Bach et al., 2024; Hahn & Klein, 2023). The present findings suggest that melancholic students' inclination toward structured thinking enables them to manage these representational transitions more effectively.

From a cognitive perspective, the results resonate with research emphasizing the role of self-regulation and effortful control in mathematical learning. Students with higher levels of self-regulation are better able to sustain attention, inhibit impulsive responses, and engage in deliberate reasoning, all of which are essential for constructing accurate mathematical representations (Blair et al., 2015; Checa et al., 2008). The melancholic temperament, characterized by persistence and reflective processing, appears to support these regulatory processes, allowing students to engage more deeply with problem structures and representational demands. This finding supports the view that representation is not merely a technical skill, but a cognitively demanding process influenced by internal regulatory capacities.

In contrast, students with a sanguine temperament demonstrated comparatively lower performance in multiple representation tasks, particularly those requiring precision and systematic transformation of information. Sanguine students are typically expressive, enthusiastic, and spontaneous, traits that may enhance engagement and communication but can also lead to less structured problem-solving approaches. The tendency to respond quickly without extensive planning may hinder their ability to organize representations coherently, especially in tasks requiring careful coordination among symbolic, graphical, and verbal forms. This pattern aligns with Ainsworth's (1999) framework, which emphasizes that successful problem solving depends on consistent integration of multiple representations rather than isolated or intuitive use of individual forms.

The findings can also be interpreted through the classical theory of mathematical problem solving, which outlines four stages: understanding the problem, devising a plan, carrying out the plan, and reviewing the solution. Each of these stages relies heavily on representational competence. Understanding a problem requires interpreting given information and constructing an initial representation of the situation; devising a plan involves selecting appropriate strategies and representational forms; carrying out the plan demands accurate manipulation of representations; and reviewing requires reflective evaluation of the solution.

The melancholic temperament appears particularly well-suited to supporting these stages due to its association with careful analysis, planning, and reflection. Conversely, sanguine students may experience difficulties in sustaining the reflective and evaluative processes required in later stages, which may explain their less systematic representational performance.

The present findings also align with contemporary research on the cognitive and emotional dimensions of problem solving. Studies have shown that emotional regulation and temperament-related traits influence students' responses to mathematical challenges, including their willingness to persist and revise strategies (Sánchez-Pérez et al., 2015; Rawlings et al., 2021). Melancholic students' tendency toward persistence and careful evaluation may foster more effective engagement with challenging representational tasks. In contrast, sanguine students heightened emotional expressiveness may increase engagement but also lead to greater susceptibility to distraction or premature closure in problem-solving processes. This interpretation reinforces the notion that mathematical learning is shaped by an interaction between cognitive processes and emotional dispositions.

In addition to temperament, the present findings can be further illuminated by considering the role of mathematics anxiety as a closely related psychological construct. Previous research has consistently demonstrated that mathematics anxiety negatively affects students' cognitive functioning, particularly in tasks requiring concentration, working memory, and logical structuring (Ashcraft & Krause, 2007; Dowker et al., 2016). Nurkarim identifies four key dimensions of anxiety. There are physiological, psychological, behavioural, and cognitive symptoms, which collectively interfere with students' mathematical performance (Nurkarim et al., 2024). These dimensions are especially relevant to mathematical representation, as anxiety-induced cognitive disruption may impair students' ability to transform information across symbolic, graphical, and verbal forms. From this perspective, the weaker representational performance observed among sanguine students in the present study may be partially explained by higher susceptibility to cognitive and behavioural symptoms of anxiety, such as impulsive responding or reduced concentration when dealing with mathematically demanding tasks.

Conversely, students with a melancholic temperament, who tend to exhibit higher levels of self-control and reflective thinking, may experience lower levels of disruptive mathematics anxiety, particularly in the cognitive domain. The SKMS framework emphasizes that cognitive symptoms, such as sudden forgetfulness, difficulty concentrating, and mental blocking directly hinder mathematical reasoning and representation

Melancholic students' greater persistence and structured thinking may function as protective factors against these symptoms, enabling them to maintain coherence across multiple representations during problem solving. This interpretation aligns with Blair et al.

(2015), who argue that self-regulation moderates the negative effects of emotional factors on mathematical cognition.

Furthermore, students' motivation toward mathematics constitutes another internal psychological factor that complements the role of temperament in shaping representational ability. There are three motivational dimensions; intrinsic goals, extrinsic goals, and perceptions of mathematics, which have been empirically linked to mathematical engagement and achievement (Nurkarim et al., 2023). Intrinsic motivation, characterized by curiosity and enjoyment of challenge, is particularly relevant for tasks involving multiple representations, as such tasks require sustained effort and conceptual exploration. Melancholic students' tendency toward deep engagement and mastery-oriented goals suggests a stronger alignment with intrinsic motivational patterns, which may explain their superior performance in constructing and coordinating mathematical representations.

In contrast, sanguine students' learning behaviours often reflect fluctuating motivation and reliance on external stimulation, which may not consistently support the sustained cognitive effort required for representational transformation. Nurkarim et al (2023) emphasize that students' perceptions of mathematics, whether they view it as meaningful, useful, and intellectually valuable significantly influence their willingness to engage deeply with mathematical tasks. When such perceptions are underdeveloped, students may approach problem solving superficially, limiting their use of systematic representations. Thus, the present study's findings suggest that temperament, motivation, and anxiety operate in an interconnected manner, jointly influencing students' representational competence.

Taken together, integrating insights from mathematics anxiety and motivation research strengthens the explanatory power of the present findings. While temperament provides a stable dispositional framework, motivational orientation and anxiety levels function as dynamic psychological mechanisms that mediate how temperament manifests in mathematical problem solving. This integrated perspective reinforces the argument that multiple representation ability is not merely a technical mathematical skill, but a complex cognitive outcome shaped by interacting psychological factors. Consequently, future instructional designs and assessment models should consider temperament alongside motivational and affective variables to more effectively support students' representational development in mathematics.

When situated within the broader literature on multiple representations, the findings of this study corroborate previous research while offering a novel perspective. Ruamba et al. (2025) emphasized the effectiveness of multimodal representations in reducing cognitive load and enhancing mathematical reasoning, primarily from an instructional design standpoint. The present study complements this work by demonstrating that the benefits of multiple representations are not uniform across learners but are mediated by individual psychological

characteristics. Similarly, Muhtarom et al. (2024) reported that Realistic Mathematics Education significantly improves representational skills, highlighting the role of pedagogical strategies. While these instructional approaches remain crucial, the current findings suggest that their effectiveness may depend partly on students' temperament, thereby underscoring the importance of considering learner variability.

The results also resonate with Wahyuni and Mubarok's (2024) findings that Problem-Based Learning integrated with multiple representations enhances problem-solving performance, though not equally for all students. Their observation that outcomes varied across learners aligns with the present study's conclusion that representational ability is influenced by internal learner characteristics. By identifying temperament as one such characteristic, this study strengthens existing evidence and extends it by providing a psychological explanation for differential responses to representational tasks.

From a pedagogical perspective, these findings have important implications for mathematics instruction. Recognizing temperament differences among students can help educators design more adaptive and responsive learning environments. For example, students with sanguine tendencies may benefit from instructional scaffolds that emphasize planning, organization, and reflection, such as structured problem-solving frameworks or guided representation tasks. Explicit instruction on how to translate between representations and opportunities for metacognitive reflection may help these students develop greater accuracy and coherence in their representations. In contrast, melancholic students may benefit from tasks that challenge them with higher-order reasoning and complex representational demands, leveraging their analytical strengths while preventing overreliance on routine procedures.

Moreover, the findings support the broader call for personalized and character-based approaches in mathematics education. Research on differentiated instruction suggests that aligning pedagogical strategies with students' psychological characteristics can enhance engagement and learning outcomes (Baten & Desoete, 2018; Rawlings et al., 2021). Incorporating strategies that promote self-regulation, emotional awareness, and metacognitive skills may be particularly effective in supporting students whose temperamental traits predispose them to less systematic problem-solving approaches. Such strategies are consistent with evidence showing that interventions targeting self-regulation and emotional control positively influence mathematical achievement (Blair et al., 2015; Wang et al., 2015).

Despite its contributions, this study has limitations that should be acknowledged. The sample size was relatively small and limited to two temperament types, which restricts the generalizability of the findings. Temperament is a multidimensional construct, and other types, such as choleric and phlegmatic, may exhibit distinct patterns of representational ability. Future research should involve larger and more diverse samples, incorporate all

temperament categories, and examine interactions between temperament, instructional design, and other cognitive variables. Longitudinal studies may also provide deeper insights into how temperament influences the development of representational skills over time.

In summary, this study demonstrates that temperament plays a significant role in shaping students' multiple mathematical representation abilities in problem solving. By linking analytical and systematic temperamental traits with higher representational performance, the findings contribute to both mathematics education and educational psychology. They reinforce the view that mathematical representation is not only a trainable cognitive skill but also an ability influenced by stable psychological characteristics. This interdisciplinary perspective opens new avenues for research and practice, emphasizing the need for adaptive instructional models that acknowledge and respond to individual differences in learners.

References

Adleff, A.-K., Ross, N., König, J., & Kaiser, G. (2023). Types of Mathematical Tasks in Lower Secondary Classrooms in Germany. *Educational Studies in Mathematics, 114*(3), 371–392. https://doi.org/10.1007/s10649-023-10254-9

Aguilar, M. S., & Castaneda, A. (2021). What Mathematical Competencies Does a Citizen Need to Interpret Mexico's Official Information About the COVID-19 Pandemic? *Educational Studies in Mathematics, 108*(1–2), 227–248. https://doi.org/10.1007/s10649-021-10082-9

Ainsworth, S. (2016). *A conceptual framework for considering learning with multiple representations*. In The Cambridge Handbook of Multimedia Learning (2nd ed., pp. 139–160). Cambridge University Press.

Ashcraft, M. H., & Krause, J. A. (2007). Working memory, math performance, and math anxiety. Psychonomic bulletin & review, 14, 243-248.

Bach, C. C., Bergqvist, E., & Jankvist, U. T. (2024). Students' Dynamic Communication While Transforming Mathematical Representations in a Dynamic Geometry Environment. *ZDM – Mathematics Education*, *56*(4), 543–557. https://doi.org/10.1007/s11858-024-01575-x

Baten, E., & Desoete, A. (2018). Mathematical (Dis)abilities Within the Opportunity-Propensity Model: The Choice of Math Test Matters. *Frontiers in Psychology*, 9. https://doi.org/10.3389/fpsyg.2018.00667

Blair, C., None, N., Ursache, A., Greenberg, M., & Vernon-Feagans, L. (2015). Multiple Aspects of Self-Regulation Uniquely Predict Mathematics but Not Letter–word Knowledge in the Early Elementary Grades. *Developmental Psychology, 51*(4), 459–472. https://doi.org/10.1037/a0038813

Checa, P., Rodríguez-Bailón, R., & Rueda, M. R. (2008). Neurocognitive and Temperamental Systems of Self-Regulation and Early Adolescents' Social and Academic Outcomes. *Mind, Brain, and Education*, *2*(4), 177–187. https://doi.org/10.1111/j.1751-228x.2008.00052.x

Clem, A.-L., Rudasill, K. M., Hirvonen, R., Aunola, K., & Kiuru, N. (2020). The Roles of Teacher–student Relationship Quality and Self-Concept of Ability in Adolescents' Achievement Emotions: Temperament as a Moderator. *European Journal of Psychology of Education, 36*(2), 263–286. https://doi.org/10.1007/s10212-020-00473-6

Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics anxiety: What have we learned in 60 years?. Frontiers in psychology, 7, 508.

Friesen, M. E., & Kuntze, S. (2020). How Context Specific Is Teachers' Analysis of How Representations Are Dealt With in Classroom Situations? Approaching a Context-Aware Measure for Teacher Noticing. *ZDM – Mathematics Education*, *53*(1), 181–193. https://doi.org/10.1007/s11858-020-01204-3

Hahn, L., & Klein, P. (2023). Clustering Eye-Movement Data Uncovers Students' Strategies for Coordinating Equations and Diagrams of Vector Fields. *Educational Studies in Mathematics*, *118*(3), 359–385. https://doi.org/10.1007/s10649-023-10243-y

Hankeln, C., & Prediger, S. (2025). Language Is Essential for Avoiding Surface Translations: Associations of Students' Spontaneous Use of Meaning-Related Phrases for Explicating Structures With Conceptual Understanding of Multiplication. *Educational Studies in Mathematics*, *120*(1), 57–79. https://doi.org/10.1007/s10649-025-10414-z

Muhtarom, A., Nurjanah, & Fatmawati, R. (2024). Pengaruh Realistic Mathematics Education terhadap Representasi Visual dalam Pemecahan Masalah. *Jurnal Pendidikan Matematika Indonesia*, 9(1), 15–24.

NCTM. (2014). *Principles to Actions: Ensuring Mathematical Success for All. Reston*, VA: National Council of Teachers of Mathematics.

Nurkarim, A. W., Qonita, W., & Isroil, A. (2024). Skala Kecemasan Matematika Siswa: Ukuran Gejala Fisiologis, Psikologis, Perilaku, dan Kognitif Matematika. *Sains Data Jurnal Studi Matematika Dan Teknologi*, *1*(2), 60–68. https://doi.org/10.52620/sainsdata.v1i2.18

Nurkarim, A. W., Qonita, W., & Monterroza, D. (2023). The students' mathematics motivation scale: a measure of intrinsic, extrinsic, and perceptions of mathematics. *International Journal on Teaching and Learning Mathematics*, *2023*(1), 42–51. https://doi.org/10.18860/ijtlm.v6i01.2023

Priyatno, D. (2020). Statistik Parametrik dengan SPSS. Yogyakarta: Mediakom.

Rawlings, A. M., Tapola, A., & Niemivirta, M. (2021). Temperamental Sensitivities Differentially Linked With Interest, Strain, and Effort Appraisals. *Frontiers in Psychology*, 11. https://doi.org/10.3389/fpsyg.2020.551806

Ruamba, L., Wulandari, D., & Surya, E. (2025). Pengaruh Multimodal Representasi Terhadap Pemahaman Konsep Matematika. *Jurnal Pendidikan Matematika dan Sains*, 10(1), 45–55.

Sánchez-Pérez, N., Fuentes, L. J., & González-Salinas, C. (2024). The Contribution of Children's Effortful Control to Math Performance Is Partially Mediated by Math Anxiety. *European Journal of Psychology of Education*, *39*(3), 2655–2679. https://doi.org/10.1007/s10212-024-00801-0

Sánchez-Pérez, N., Fuentes, L. J., Pina, V., López-López, J. A., & González-Salinas, C. (2015). How Do Different Components of Effortful Control Contribute to Children's Mathematics Achievement? *Frontiers in Psychology*, 6. https://doi.org/10.3389/fpsyg.2015.01383

Sugiyono. (2019). Metode Penelitian Kuantitatif, Kualitatif, dan R&D. Bandung: Alfabeta.

Wahyuni, I., & Mubarok, S. (2024). Efektivitas Problem Based Learning berbasis Multiple Representations terhadap Kemampuan Pemecahan Masalah. *Jurnal Pendidikan dan Inovasi Kurikulum*, 12(1), 101–112.

Wang, Z., Soden, B., Deater-Deckard, K., Lukowski, S. L., Schenker, V. J., Willcutt, E. G., Thompson, L. A., & Petrill, S. A. (2015). Development in Reading and Math in Children From Different <scp>SES</Scp> Backgrounds: The Moderating Role of Child Temperament. *Developmental Science*, *20*(3). https://doi.org/10.1111/desc.12380