International Journal of Evaluation and Research in Education (IJERE)
Vol. 13, No. 5, October 2024, pp. 3130~3138
ISSN: 2252-8822, DOI: 10.11591/ijere.v13i5.29609

The effect of the mathematics instruction model on enhancing mathematical thinking

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Article Info

Article history:

Received Dec 13, 2023
Revised Jan 21, 2024
Accepted Feb 12, 2024

Keywords:

Learning activities
Mathematical thinking
Mathematics instruction model
Model-eliciting activities
Realistic mathematics education
Satisfaction

ABSTRACT

The objectives of this research were to study the efficacy of the mathematics instructional model (BRIGHT model) based on realistic mathematics education (RME) and model-eliciting activities (MEAs) approaches to enhance mathematical thinking (MT) for upper primary school students as follows: i) to compare the mathematics achievement of students before and after studying with the BRIGHT model, ii) to compare the MT of students before and after studying with the BRIGHT model, and iii) to evaluate the students' and mathematic teachers' satisfaction on learning activities by using the BRIGHT model. The results of this research were as follows: i) the mathematics achievement and MT of students after studying were significantly higher than before studying with the BRIGHT model; ii) the student satisfaction with learning activities using the BRIGHT model was satisfied all aspects of the assessment. The mean scores from highest to lowest were as follows: benefits that student received, learning atmosphere, and learning activities, respectively; and iii) the satisfaction teachers and educational superiors were very satisfied with the learning management process and applying the BRIGHT model. Therefore, learning through the BRIGHT mathematical modeling has shown all aspects of students' and mathematic teachers' expected development.

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1. INTRODUCTION

Mathematical thinking (MT) is closely related to the ability to solve problems in everyday life. Therefore, MT is an important skill that is a goal for learning in everyday life and serves as a guideline for effective mathematics learning [1]. Understanding the nature of mathematics and the level of MT development of students is a crucial factor in planning the mathematics learning process. The nature of mathematics is abstract, factual, and symbolic which is difficult for students to understand. Therefore, teachers played a critical role in students' learning achievement by adjusting mathematics instruction to the developmental level of students' MT [2]. The sub-dimensions of MT consisted of advanced thinking processes, reasoning skills, competence in MT abilities, and adeptness in solving problems [3]. Previous studies have shown that the application of realistic mathematics education (RME) corresponds to effective learning practices [4]–[6]. RME involves connecting mathematical concepts with real-life situations and relating to student's experiences to encourage students to practice logical thinking and imagination [7], [8]. Learning with RME is conducted through a series of activities with the aim of allowing students to build understanding of the content through discussion with classmates, sharing opinions, suggestions, and teachers are responsible for guiding students during the presentation of ideas [9]. Furthermore, by learning mathematics related to the real world according to the student's ideas, it was discovered that they also contemplated mathematical problem-solving as a means to incorporate mathematics into their daily lives [10]. In addition, model-eliciting activities (MEAs) concept is a problem-solving concept in which students create solutions based on more than one hypothesis to summarize the created problem-solving model and emphasize group problem-solving in order to encourage students to come up with solutions to different real-life problems [11]. It was found that the cognitive process of problem-solving is involved in the resolution of mathematical problems. Several studies have shown that students who are able to solve problems having new experiences that can be used as a basis for solving more complex problems [12]–[14].

It indicated that mathematical problem-solving skills are important for the learning development of students. It is in accordance with the principles of the mathematics BRIGHT model based on the RME concept with MEAs to enhance MT for upper primary school students, it exhibited that mathematics learning is organized by allowing students to learn from concrete to abstract things. Using problems from situations that correspond to reality context in the real world and experiences according to the interests of the students through a learning process that emphasizes on having students take action and create a problem-solving process on their own. Using a cooperative learning process and presenting a problem-solving process that logically connects mathematical knowledge including leading the process to solve problems that have been created and can be used to solve problems in other situations in everyday life and reflect on what has been learned [15]. From the preliminary study mentioned above, the researcher realized the importance of conducting a research study with upper primary students. Therefore, in this research, the researcher aims:

i). To study and compare the mathematics achievement and MT of students before studying and after studying with the BRIGHT model based on the RME and MEAs to enhance MT for upper primary students.
ii). To satisfaction of students and mathematics teachers with the mathematical educational model.

It is hypothesized that the mathematics achievement and MT of students after studying with the BRIGHT model are higher than before studying. In addition, students and teachers are at a high level of satisfaction with the BRIGHT model.

2. THE COMPREHENSIVE THEORETICAL BASIS

2.1. Mathematical thinking (MT)

MT is a mathematical process that includes mathematical understanding, mathematical communication, mathematical connections, mathematical reasoning, and mathematical solving problems in order to understand mathematics correctly [16]. Important elements of MT include: i) mathematical problem-solving, which is planning the implementation of problem-solving using various strategies or methods to solve problems and adapting them appropriately, and ii) mathematical reasoning, which is using a variety of tests that reason according to mathematical principles. The development of MT must take into an important factor necessary for structuring mathematics learning as follows: i) the possibility of MT; ii) MT can be developed by answering questions and practice through reflection; iii) MT can be stimulated by interesting situations, problems, or conflicts; iv) MT can be supported by an atmosphere of inquiry, challenge, and reflection; and v) learning MT helps students better understand the reality of the world [17]. MT can be measured by the following indicators: i) identify problems, develop and try strategies; various that can be used to solve problems; ii) extend success results; iii) compare similar cases; and iv) identify reasons for success in solving problems [1].

2.2. Realistic mathematics education (RME)

RME has a view that mathematics is connected to real life, close to the learner's experiences and relevant to the social context, so that mathematics is a valuable subject for learning instead of mathematics being just a subject. But mathematics is a human activity. Learning mathematics should give students the opportunity to invent mathematics through practice [18]. From the study, it was found that the principles of RME consisted of 5 principles: i) the principle of reality and phenomenology, ii) the principle of activity, iii) the principle of integration and connection, iv) the principle of interaction and reflection, and v) the principle of hierarchy. Therefore, organizing learning activities according to the RME concept consists of i) using contextual problems in which the selection of context depends on the experiences of the learners, ii) creating simulation models, iii) activities that allow learners to discuss, express their opinions and find solutions through group processes, iv) interaction between teachers in pointing out problems for students to learn to solve problems, and v) connecting knowledge [18], [19]. This is a process that encourages students to think actively, to create your own knowledge, and to learn that is directly related to the school environment and learners. Authentic education is a learning approach that begins with contextual problems to guide learners to understand mathematical concepts and learn mathematics relevant to everyday life.

2.3. Model-eliciting activities (MEAs)

The MEAs is a concept that is consistent with real-life mathematics education problems, which is developed to encourage students to create mathematical models to solve complex problems and has methods to understand the thinking process of students. It was found that the principles according to the MEAs concept consisted of 6 principles: i) modeling principles, ii) reality principles, iii) self-evaluation principles, iv) idea explanation principles, v) exchange and adaptation principles, and vi) effective model principles. There are researchers who have introduced the concept of MEAs has been used in research. For example, Pertamawati and Retnowati [20] studied the concept of MEAs to enable students to create, test, and edit mathematical models during the learning process. The results show that the implementation of MEAs concepts can prepare students to solve real-life problems by applying the mathematical concepts that are studied in schools. Moreover, MEAs are considered a tool for developing and creating mathematical understanding for students. Qurohman *et al.* [21] studied the influence of MEAs concepts on the development of mathematical problem-solving abilities. It was found that learners who learned according to the MEAs concept had higher problem-solving abilities than those who learned in general.

3. METHOD

3.1. Population and sample

The population of the present research was the primary 4-6 students grades from 6 schools under the Kanchanaburi Educational Service Area Office, Area 1, due to the students' basic national educational tests in mathematics subjects were below the assessment criteria. To determine the sample size, the researcher used the sample size determination with the G*Power 3.1.9.7 program [22], [23], created from the formula of Cohen [24]. From the previous studies, it was found that the mean effect size was equal to 0.929, the acceptable error value to be equal to .05 and the power of the statistical test to be equal to 0.95, it showed that the sample size was 15 people [25]–[27]. The samples used in the trial of the BRIGHT model were 36 primary 5 grades students under Kanchanaburi Primary Educational Service Area Office 1, obtained from multi-stage sampling in 3 steps: i) school level sampling from 6 schools, 1 school was randomly selected; ii) class level sampling, divided into the primary 4 grades, the primary 5 grades and the primary 6 grades, randomly assigned to the primary 5 grades; and iii) classroom level randomization, totaling 3 classrooms, and then randomly assigned for 1 classroom of primary 5 grades. There are a total of 36 students. Therefore, the sample size of 36 people is sufficient for the research. In addition, the samples used in the publication of BRIGHT model consisted of 36 mathematics teachers who teach at the upper primary level and 5 educational supervisors under Kanchanaburi Primary Educational Service Area Office 1, obtained through volunteer methods.

3.2. Data collection and data analysis

This research utilized a single-group design with pre-test and post-test measurements to investigate the efficacy of the BRIGHT model in enhancing mathematical understanding of quadrilaterals among primary 5 students for 25 hours. The research instruments were i) the mathematics achievement test is a standardized assessment consisting of 25 multiple-choice questions. The test design was based on the concept of Wilson [28] framework which classified intellectual behavior in mathematics learning into four distinct levels including computational thinking, understanding, application, and analysis. The accuracy value (reliability) is 0.801, ii) the MT test consists of a two-item essay test. The given situation represents a mathematical problem that corresponds with the learner's everyday circumstances. The content of the problem was intended to include the elements of MT, which encompass four indicative behaviors including problem analysis and knowledge evaluation, knowledge design/planning and linking, problem-solving implementation, and reasonableness evaluation [15]. The accuracy value (reliability) is 0.924, and iii) the questionnaire on perspectives and satisfaction with learning activities. The instrument used in this study was a questionnaire including a 5-point Likert scale, which was divided into three distinct domains: i) learning activities, ii) learning atmosphere, and iii) advantages received by students. The IOC index value is within ranges from 0.80 to 1.00.

The dissemination and exchanging knowledge of the results of the trial using the teaching model can be by organizing academic conferences via an online platform. This approach allows participants to actively participate by expressing their ideas and insights through a questionnaire. The questionnaire uses a 5-point Likert scale, that was divided into two distinct sections. The IOC index value for the instructional method and its implementation were within ranges from 0.80 to 1.00.

4. RESULTS AND DISCUSSION
4.1. Student mathematical achievement

To compare the mathematical achievement of students before and after studying with the BRIGHT model based on RME and MEAs as shown in Table 1. The mean score after studying (M=17.472, SD=2.602) was significantly higher than before studying (M=7.611, SD=2.246). Due to the principles of the teaching model emphasize the utilization of realistic problems and the establishment of linkages between mathematics and other sciences within the context of students' experiences. In addition, it emphasizes the learning process in which students practice creating problem-solving processes on their own and the learning process creates mutual interaction between the learners. This is consistent with the concepts of RME and MEAs that learning mathematics is part of real life and helps encourage learners to create their own problem-solving processes [18]–[21]. It is also consistent with Siregar *et al.* [29] found that the academic achievement of the students who learned mathematics according to the RME concept increased significantly when compared to those students who studied normally, and Wulandari *et al.* [30] also found that organizing learning according to the MEAs concept was very effective in developing the ability to students' mathematical problem-solving and reflective thinking compared to conventional learning.

Table 1. Comparative the mean score (M) and standard deviation (SD) of students' mathematics achievement before studying and after studying with the BRIGHT model

Achievement	n	Full Marks	M	SD	*t*	Sig.
Before	36	25	7.611	2.246	*20.907	001.
After	36	25	17.472	2.602		

Statistically significance differences between before and after studying with the BRIGHT model are indicated by $*p<0.05$.

4.2. Mathematical thinking of students

The results of the MT test before and after the use of the BRIGHT model revealed that the average score for MT after studying with the instructional approach (M=20.944, SD=3.854) was higher than the average score prior to studying (M=6.167, SD=1.521), as presented in Table 2. When considering each element, it was found that the average MT score after studying was significantly higher than before studying in all dimensions of the assessments as follows: i) there was a significant increase in the ability to analyze issues and evaluate knowledge after learning (M=7.583, SD=1.228), compared to the mean score before studying (M=5.556, SD=1.081), ii) the process of designing/planning and the ability to connect knowledge exhibited a higher mean score (M=5.861, SD=1.417) after studying compared to the mean score before studying (M=3.06, SD=5.861), iii) the results indicate that there was a significant increase in problem-solving ability after learning (M=4.361, SD=1.641) compared to before studying (M=0.306, SD=0.525), and iv) the evaluation of reasonableness showed a significant improvement after studying (M=3.139, SD=1.291) compared to before studying (M=0.000, SD=0.000).

Students' MT was higher after studying with the BRIGHT model because the rationale for the adoption of the researcher's teaching model is in alignment with the theoretical framework of RME and MEAs which emphasizes the integration of mathematics education with real-life contexts by solving problems systematically and logically [18]–[21] and according to the important elements of MT that include using strategies to solve problems based on mathematical reasoning and being able to guide solutions to other similar situations [1], [16], [17]. This approach entails structuring mathematics instruction around problem situations, context or activity pertaining to the practical aspects of human existence, involving the resolution of challenges and the consolidation of knowledge, context, or activity related to living life in the real world of humans through the process of solving problems to summarizing knowledge, concepts, strategies, or ideas in which learners can express the structure of their thinking process creatively and solve real problems are in accordance with the principles of the theory of self-knowledge creation (constructivism) and cooperative learning that is learners independently acquire knowledge and comprehension through experiential learning, thereby generating meaningful insights for themselves. This corresponds to the findings of Anggraini and Fauzan [31], that students' proficiency in solving mathematical problems is greater when learning is guided by the RME approach compared to traditional instructional methods. Consequently, RME promotes the enhancement of students' problem-solving skills in mathematics. Uskun *et al.* [32] also found that learners who were subjected to learning based on the RME concept showed enhanced comprehension of problem situations and increases students' academic achievement on national tests. According to the study performed by Kharisudin and Cahyati [33], learners possess an increased ability to effectively address problem-solving tasks utilizing the mathematical modeling procedure based on the concept of MEAs, as compared to conventional learning models. Furthermore, they have an excellent understanding of fundamental mathematical concepts whereas engaged in the resolution of mathematical problems. Hartati *et al.* [34] discovered that the concept of MEAs has a significant impact on students' proficiency in mathematical problem-solving and their development of MT skills. The implementation of the MEAs concept proves to be highly effective in enhancing students' problem-solving abilities and reflective thinking skills in mathematics.

Table 2. Comparative the M and SD of students' MT before studying and after studying with the BRIGHT model

Mathematical thinking	n	Full marks	Before		After		t	Sig.
			M	SD	M	SD		
Part 1: analyze problems and evaluate knowledge	36	8	5.556	1.081	7.583	1.228	8.544*	001.
Part 2: design/planning and connecting knowledge	36	8	0.306	0.525	5.861	1.417	23.098*	001.
Part 3: troubleshooting procedures	36	8	0.306	0.525	4.361	1.641	16.106*	001.
Part 4: evaluate reasonableness	36	8	0.000	0.000	3.139	1.291	14.592*	001.
Total	36	32	6.167	1.521	20.944	3.854	24.139*	001.

Statistically significance differences between before and after studying with the BRIGHT model are indicated by * p<0.05.

4.3. Students' satisfaction on learning activities using BRIGHT model

The results of evaluating students' satisfaction on learning activities after studying with the BRIGHT model. It was found that, overall, the students were satisfied toward learning activities (M=4.227, SD=0.4222). Upon consideration of each element, the results demonstrated satisfied level across all evaluated dimensions. The mean scores from highest to lowest were as follows: i) benefits that student received (M=4.265, SD=0.473), ii) learning atmosphere (M=4.206, SD=0.474), and iii) learning activities (M=4.178, SD=0.478), respectively, as shown in Table 3. Evaluation of students' satisfaction with the learning activities after studying with the BRIGHT model found that the level of student satisfaction with the learning activities was at a high level in all aspects. Due to the learning management system aligns with the principles of active learning that emphasizes allowing students to participate in collaborative problem-solving activities and implement the knowledge gained from the solutions they generate [35]. In addition, the knowledge from solving problems created can be used to solve problems in other situations that are consistent with real life, including creating a learning atmosphere of the teachers that affects students' learning of mathematics, which is consistent with Da [36] studied the development of a context-based MT learning model to increase advanced thinking ability. It was found that mathematics learning activities in the classroom support the development of advanced thinking ability and help students learn mathematics in a real-life context, which is consistent with Laine *et al.* [37], the designing a teaching model based on the RME approach and its application in teaching calculus. It has been found that students are more enthusiastic and motivated to learn and this has a positive effect on the development of academic achievement. It also found that the impact of teachers' actions plays an important role in creating an emotional atmosphere in elementary school mathematics learning. A positive emotional atmosphere can be created when teachers encourage students to discuss mathematics with their classmates [38].

Table 3. Comparative the M and SD of evaluating students' satisfaction on learning activities after studying with the BRIGHT model

List of evaluations	Evaluation findings		
	M	SD	Interpret results
Side 1: Learning activities	4.178	0.478	Satisfied
1) Connect mathematical knowledge to daily life	4.028	0.696	Satisfied
2) Stimulate interest in learning mathematics	4.306	0.668	Satisfied
3) Promote self-directed search for knowledge	4.083	0.841	Satisfied
4) Promote the exchange of knowledge between friends and teachers	4.222	0.797	Satisfied
5) Promote mathematical thinking processes	4.250	0.649	Satisfied
Side 2: Learning atmosphere	4.206	0.474	Satisfied
1) It's independent in expressing your opinions	4.139	0.798	Satisfied
2) It's interesting to learn	4.306	0.668	Satisfied
3) There is a challenge to solve mathematical problems	4.222	0.722	Satisfied
4) There is a facilitation of working with others	4.222	0.681	Satisfied
5) It promotes enthusiasm for learning	4.139	0.683	Satisfied
Side 3: Benefits that students received	4.265	0.473	Satisfied
1) Students get to practice the activities on their own	4.333	0.632	Satisfied
2) Students participate in group activities	4.306	0.710	Satisfied
3) Students learn mathematics that is connected to daily life	4.306	0.668	Satisfied
4) Students solve problems through mathematical thinking processes	4.139	0.683	Satisfied
5) Students demonstrate mathematical reasoning through the problem solving process	4.111	0.785	Satisfied
6) Students work through group processes	4.278	0.779	Satisfied
7) Students practice mathematical thinking processes in both individual and group activities	4.444	0.735	Satisfied
8) Students have the ability to think mathematically	4.167	0.697	Satisfied
9) Students can apply knowledge in their daily lives	4.306	0.668	Satisfied
Total	4.227	0.422	Satisfied

4.4. Teachers and educational supervisors satisfaction on learning activities using BRIGHT model

The results of evaluating teachers' and educational supervisors' satisfaction with learning activities using BRIGHT model, were very satisfactory (M=4.813, SD=0.288), consistent with the satisfaction of the educational supervisors. Overall, it was very satisfactory (M=5.000, SD=0.000) as shown in Table 4. The current mathematics teaching focuses on academic achievement rather than the learning process that occurs for students. Therefore, the meeting participants paid attention to MT, which is considered a learning process that should be promoted to learners from the upper primary level and is a learning arrangement that emphasizes learners being expressions, creating a problem-solving process, and presenting the problem-solving process created by yourself, consistent with the Szabo *et al.* [39] and the development of skills in the 12th century [40], [41], which mentions the promotion of learning management through a teaching process that emphasizes having students participate and interact with learning activities through a variety of active learning activities, there is measurement and evaluation in the classroom for the development of learning and competencies of students for all assessment learning [42].

Table 4. Comparative the M and SD of evaluating teacher and educational supervisors' satisfaction on learning activities after studying with the BRIGHT model

List of evaluations	Evaluation findings					
	Mathematics teachers			Educational supervisors		
	M	SD	Interpret results	M	SD	Interpret results
1. Learning management process	4.830	0.281	Very satisfied	5.000	0.000	Very satisfied
1) It is a sequence of continuous steps	4.889	0.319	Very satisfied	5.000	0.000	Very satisfied
2) It can be used to organize teaching and learning activities to achieve the objectives	4.833	0.378	Very satisfied	5.000	0.000	Very satisfied
3) It is consistent with principles and objectives	4.889	0.319	Very satisfied	5.000	0.000	Very satisfied
4) It promotes mathematical thinking processes	4.861	0.351	Very satisfied	5.000	0.000	Very satisfied
5) It describes the nature of activities that can be used as guidelines for actual classroom practice	4.806	0.401	Very satisfied	5.000	0.000	Very satisfied
6) It specifies learner roles as guidelines for organizing learning activities	4.806	0.401	Very satisfied	5.000	0.000	Very satisfied
7) It specifies the instructor's role as a guideline for organizing learning activities	4.861	0.351	Very satisfied	5.000	0.000	Very satisfied
8) Summarizing the goals in each step in organizing learning helps to understand the concept of the teaching model	4.833	0.378	Very satisfied	5.000	0.000	Very satisfied
9) Guidelines for measurement and evaluation are consistent with principles and objective	4.889	0.319	Very satisfied	5.000	0.000	Very satisfied
10) Each step of learning management is supported by principles, concepts, and theories	4.750	0.439	Very satisfied	5.000	0.000	Very satisfied
11) Learning management process is clear						
11.1) Stage of basic idea	4.833	0.378	Very satisfied	5.000	0.000	Very satisfied
11.2) Stage of connecting reality	4.778	0.485	Very satisfied	5.000	0.000	Very satisfied
11.3) Stage of creating ideas through group processes	4.861	0.351	Very satisfied	5.000	0.000	Very satisfied
11.4) Stage of revealing thoughts	4.806	0.401	Very satisfied	5.000	0.000	Very satisfied
11.5) Stage of Cognitive thinking	4.861	0.351	Very satisfied	5.000	0.000	Very satisfied
12) The teaching model diagram clearly conveys the meaning of the process	4.722	0.454	Very satisfied	5.000	0.000	Very satisfied
2. Applying the BRIGHT model	4.778	0.422	Very satisfied	5.000	0.000	Very satisfied
1) Students learn mathematics that is connected to daily life	4.750	0.439	Very satisfied	5.000	0.000	Very satisfied
2) Students are stimulated to be interested in learning mathematics	4.861	0.351	Very satisfied	5.000	0.000	Very satisfied
3) Students get to practice the activities on their own	4.806	0.401	Very satisfied	5.000	0.000	Very satisfied
4) Students exchange knowledge with friends and teachers	4.806	0.401	Very satisfied	5.000	0.000	Very satisfied
5) Students solve problems through mathematical thinking processes	4.750	0.439	Very satisfied	5.000	0.000	Very satisfied
6) Students are challenged to solve mathematical problems	4.667	0.478	Very satisfied	5.000	0.000	Very satisfied
7) Students demonstrate mathematical reasoning through the problem-solving process	4.806	0.401	Very satisfied	5.000	0.000	Very satisfied
8) Students participate in joint activities through group processes	4.778	0.316	Very satisfied	5.000	0.000	Very satisfied
Total	4.813	0.288	Very satisfied	5.000	0.000	Very satisfied

Developing MT with the BRIGHT model teaching format is consistent with the goals of Thailand's national strategy to develop human resources in mathematics and the Ministry of Education's policy to raise the quality of education that emphasizes learning from the real practice emphasizes the development of necessary skills and competencies [43]. MT is considered a skill that should be developed for learners from the primary school level in order to apply it in real life and raise the quality of education in Thailand [44], [45]. The BRIGHT model process is consistent with Program for International Student Assessment (PISA) mathematical assessment framework that focuses on interpreting a mathematical result back into the real-world context, evaluating the reasonableness of a mathematical solution in the context of a real world problem, and understanding how the real world impacts the outcomes and calculations of a mathematical procedure or model in order to make contextual judgments about how the results should be adjusted or applied which will provide a basis for learners who can connect mathematics to mathematical procedures mathematics and real life [46].

5. CONCLUSION

The efficacy of the BRIGHT model based on RME and MEAs approaches to enhance MT for upper primary students, it is a teaching model that promotes and develops MT processes by using challenging problem situations that are consistent with students' real lives to stimulate problem-based learning and use grouping processes allowing students to think, analyze, and solve problems together. However, mathematics teachers at the upper primary school should use the results of this study as a database to consider in applying the teaching model according to the appropriateness of the content and giving importance to the development of critical mathematics thinking in the process of solving mathematical problems and checking for reasonableness.

ACKNOWLEDGEMENTS

This research work was supported by National Research Council of Thailand (NRCT) (173844).

REFERENCES

[1] F. Ferdianto, Y. L. Sukestiyarno, W. Widowati, and I. Junaedi, "Mathematical thinking process on numeracy literacy problems for middle school students," *Journal of Positive School Psychology*, vol. 6, no. 8, pp. 6909–6923, 2022, [Online]. Available: https://journalppw.com/index.php/jpsp/article/view/11007/7110.

[2] V. F. Falentina, A. Muchyidin, and T. S. Nasehudin, "Van Hiele's theory and think pair share cooperative learning model and their effect on madrasah tsanawiyah student's level of mathematical thinking," *Journal of General Education and Humanities*, vol. 1, no. 1, pp. 1–11, Feb. 2022, doi: 10.58421/gehu.v1i1.2.

[3] H. C. Çelik and F. Özdemir, "Mathematical thinking as a predictor of critical thinking dispositions of pre-service mathematics teachers," *International Journal of Progressive Education*, vol. 16, no. 4, pp. 81–98, Aug. 2020, doi: 10.29329/ijpe.2020.268.6.

[4] D. Pratiwi, R. Ruslan, and H. Upu, "The effectiveness of mathematics learning through the application of realistic mathematics education (RME) approach from numeric intelligence in class VII students of SMP Negeri 3 Pallangga, Gowa Regency," in *Proceedings of the International Conference on Educational Studies in Mathematics (ICoESM 2021)*, Dec. 2021, pp. 196–203, doi: 10.2991/assehr.k.211211.033.

[5] B. P. Uyen, D. H. Tong, N. P. Loc, and L. N. P. Thanh, "The effectiveness of applying realistic mathematics education approach in teaching statistics in grade 7 to students' mathematical skills," *Journal of Education and e-Learning Research*, vol. 8, no. 2, pp. 185–197, Apr. 2021, doi: 10.20448/journal.509.2021.82.185.197.

[6] E. Dewi, "The effect of RME-based e-module on students' creative thinking in mathematics," *Instructional Media for Mathematics*, vol. 1, no. 1, pp. 30–37, Jun. 2023.

[7] M. K. Altay, B. Yalvaç, and E. Yeltekin, "8th grade student's skill of connecting mathematics to real life," *Journal of Education and Training Studies*, vol. 5, no. 10, pp. 158–166, Sep. 2017, doi: 10.11114/jets.v5i10.2614.

[8] D. Elpina, H. Syarifuddin, and Y. Yerizon, "Development of realistic mathematics education based learning device to improve students' mathematical connection," *Journal of Physics: Conference Series*, vol. 1554, no. 1, p. 012014, May 2020, doi: 10.1088/1742-6596/1554/1/012014.

[9] N. Nuryami, S. Sunardi, S. Susanto, P. Rizqika, and A. Shofyan, "The development of learning tool based on realistic mathematics education and its influence on spatial abilities of elementary school students," *Journal of Physics: Conference Series*, vol. 1839, no. 1, p. 012013, Mar. 2021, doi: 10.1088/1742-6596/1839/1/012013.

[10] A. Miranda, "Thinking groups and the development of affective problem-solving competencies in online learning environments at the university level," in *Higher Education Learning Methodologies and Technologies Online (HELMeTO 2022)*, 2023, pp. 719–732, doi: 10.1007/978-3-031-29800-4_54.

[11] İ. Kaygısız and E. A. Şenel, "Investigating mathematical modeling competencies of primary school students: Reflections from a model eliciting activity," *Journal of Pedagogical Research*, vol. 7, no. 1, pp. 1–24, Jan. 2023, doi: 10.33902/JPR.202317062.

[12] M. G. Gurat, "Mathematical problem-solving strategies among student teachers," *Journal on Efficiency and Responsibility in Education and Science*, vol. 11, no. 3, pp. 53–64, Sep. 2018, doi: 10.7160/eriesj.2018.110302.

[13] S. Osman, C. N. A. C. Yang, M. S. Abu, N. Ismail, H. Jambari, and J. A. Kumar, "Enhancing students' mathematical problem-solving skills through bar model visualisation technique," *International Electronic Journal of Mathematics Education*, vol. 13, no. 3, pp. 273–279, Oct. 2018, doi: 10.12973/iejme/3919.

[14] B. Sinaga, J. Sitorus, and T. Situmeang, "The influence of students' problem-solving understanding and results of students' mathematics learning," *Frontiers in Education*, vol. 8, p. 1088556, Feb. 2023, doi: 10.3389/feduc.2023.1088556.
[15] N. Iamcham, S. Chanchusakun, and P. Kitroongrueng, "BRIGHT model mathematics instructional model based on RME and MEAs approaches to enhance mathematical thinking for upper primary students," (in Thai), *Journal of Humanities and Social Sciences Nakhon Phanom University*, vol. 13, no. 1, pp. 277–293, Apr. 2023, [Online]. Available: https://so03.tci-thaijo.org/index.php/npuj/article/ view/266354/177188.
[16] S. Heleni and Z. Zulkarnain, "The influence of mathematical thinking ability with modified MOORE method on learning outcomes of basic mathematic II chemical education students," *Journal of Educational Sciences*, vol. 2, no. 2, pp. 33–41, Jul. 2018, doi: 10.31258/jes.2.2.p.33-41.
[17] J. Mason, L. Burton, and K. Stacey, *Thinking mathematically*, 2nd ed. London: Pearson, 2010.
[18] K. Pantaranontaka, W. Sawekngam, and A. Makanong, "Development of an instructional model based on mathematization approach and realistic mathematics education to enhance mathematical problem solving and reasoning abilities of lower-secondary school students," (in Thai), *Journal of Education Studies*, vol. 48, no. 3, pp. 21–40, Sep. 2020, [Online]. Available: https://so02.tci-thaijo.org/index.php/EDUCU/article/view/244978.
[19] M. Van den Heuvel-Panhuizen, "A spotlight on mathematics education in the Netherlands and the central role of realistic mathematics education," in *National Reflections on the Netherlands Didactics of Mathematics*, M. Van den Heuvel-Panhuizen, Ed. Springer International Publishing, 2020, pp. 1–14, doi: 10.1007/978-3-030-33824-4_1.
[20] L. Pertamawati and E. Retnowati, "Model-eliciting activities: engaging students to make sense of the world," *Journal of Physics: Conference Series*, vol. 1200, p. 012003, Mar. 2019, doi: 10.1088/1742-6596/1200/1/012003.
[21] M. T. Qurohman, P. P. Nugraha, S. A. Romadhon, and A. S. Fathurrohman, "The influence of model of eliciting activities on improving mathematical problem-solving ability," *International Journal of Trends in Mathematics Education Research*, vol. 5, no. 2, pp. 141–146, Jun. 2022, doi: 10.33122/ijtmer.v5i2.125.
[22] F. Faul, E. Erdfelder, A. Buchner, and A. G. Lang, G* Power 3.1.9.7. (2020). [Online]. Available: https://www.psychologie.hhu.de/arbeitsgruppen/allgemeine-psychologie-und-arbeitspsychologie/gpower.
[23] J.-C. Goulet-Pelletier and D. Cousineau, "A review of effect sizes and their confidence intervals, Part I: The Cohen's d family," *The Quantitative Methods for Psychology*, vol. 14, no. 4, pp. 242–265, Dec. 2018, doi: 10.20982/tqmp.14.4.p242.
[24] J. Cohen, *Statistical power analysis for the behavioral sciences*. New York: Academic Press, 2013.
[25] M. Herman, I. M. Arnawa, and A. Ardipal, "The effect of realistic mathematic education (RME) toward motivation and learning achievement of the fourth grade elementary students," in *Proceedings of the 1st International Conference on Innovation in Education (ICoIE 2018)*, Jan. 2019, doi: 10.2991/icoie-18.2019.109.
[26] N. Sumarna, W. Wahyudin, and T. Herman, "The increase of critical thinking skills through mathematical investigation approach," *Journal of Physics: Conference Series*, vol. 812, no. 1, p. 012067, Feb. 2017, doi: 10.1088/1742-6596/812/1/012067.
[27] B. Altaylar and S. Kazak, "The effect of realistic mathematics education on sixth grade students' statistical thinking," *Acta Didactica Napocensia*, vol. 14, no. 1, pp. 76–90, Jul. 2021, doi: 10.24193/adn.14.1.6.
[28] J. W. Wilson, *Handbook on formative and summative evaluation of student learning*. New York: McGraw-Hill, 1971.
[29] R. N. Siregar, D. Suryadi, S. Prabawanto, and A. Mujib, "Improving student learning: mathematical reasoning ability through a realistic mathematic education," *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, vol. 11, no. 4, pp. 2698–2713, Dec. 2022, doi: 10.24127/ajpm.v11i4.6250.
[30] D. Wulandari, B. S. Narmaditya, S. H. Utomo, and P. H. Prayitno, "Teachers' perception on classroom action research," *KnE Social Sciences*, vol. 3, no. 11, pp. 313–320, Mar. 2019, doi: 10.18502/kss.v3i11.4015.
[31] R. S. Anggraini and A. Fauzan, "The effect of realistic mathematics education approach on mathematical problem solving ability," *Edumatika: Jurnal Riset Pendidikan Matematika*, vol. 3, no. 2, pp. 94–102, Aug. 2020, doi: 10.32939/ejrpm.v3i2.595.
[32] K. A. Uskun, O. Çil, and O. Kuzu, "The effect of realistic mathematics education on fourth graders' problem posing/problem-solving skills and academic achievement," *Journal of Qualitative Research in Education*, vol. 21, no. 28, pp. 22–50, Oct. 2021, doi: 10.14689/enad.28.2.
[33] I. Kharisudin and N. E. Cahyati, "Problem-solving ability using mathematical modeling strategy on model eliciting activities based on mathematics self-concept," *Journal of Physics: Conference Series*, vol. 1567, no. 3, p. 032067, Jun. 2020, doi: 10.1088/1742-6596/1567/3/032067.
[34] S. Hartati, R. A. Bilqis, and A. Rinaldi, "Mathematical problem-solving abilities and reflective thinking abilities: The impact of the influence of eliciting activities models," *Al-Jabar: Jurnal Pendidikan Matematika*, vol. 11, no. 1, pp. 167–178, Jun. 2020, doi: 10.24042/ajpm.v11i1.6709.
[35] R. Koskinen and H. Pitkäniemi, "Meaningful learning in mathematics: a research synthesis of teaching approaches," *International Electronic Journal of Mathematics Education*, vol. 17, no. 2, p. em0679, Feb. 2022, doi: 10.29333/iejme/11715.
[36] N. T. Da, "Designing a teaching model based on the Realistic Mathematics Education (RME) approach and its application in teaching calculus," *Journal of Mathematics and Science Teacher*, vol. 2, no. 1, p. em006, Mar. 2022, doi: 10.29333/mathsciteacher/11918.
[37] A. Laine, M. Ahtee, and L. Näveri, "Impact of teacher's actions on emotional atmosphere in mathematics lessons in primary school," *International Journal of Science and Mathematics Education*, vol. 18, no. 1, pp. 163–181, Jan. 2020, doi: 10.1007/s10763-018-09948-x.
[38] Office of the Basic Education Commission, "Quick policy 2021," 2021, [Online]. Available: https://www.obec.go.th.
[39] Z. K. Szabo, P. Körtesi, J. Guncaga, D. Szabo, and R. Neag, "Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills," *Sustainability*, vol. 12, no. 23, p. 10113, Dec. 2020, doi: 10.3390/su122310113.
[40] J. Suh, K. Matson, P. Seshaiyer, S. Jamieson, and H. Tate, "Mathematical modeling as a catalyst for equitable mathematics instruction: preparing teachers and young learners with 21st century skills," *Mathematics*, vol. 9, no. 2, p. 162, Jan. 2021, doi: 10.3390/math9020162.
[41] C. Hikayat, S. Suparman, Y. Hairun, and H. Suharna, "Design of realistic mathematics education approach to improve critical thinking skills," *Universal Journal of Educational Research*, vol. 8, no. 6, pp. 2232–2244, Jun. 2020, doi: 10.13189/ujer.2020.080606.
[42] F. Anwar, "Activity-based teaching, student motivation and academic achievement," *Journal of Education and Educational Development*, vol. 6, no. 1, pp. 154–170, May 2019, doi: 10.22555/joeed.v6i1.1782.
[43] National Strategy Secretariat Office, Office of the National Economic and Social Development Board, "Thailand 20-year national strategy plan," 2018, [Online]. Available: https://www.ratchakitcha.soc.go.th/DATA/PDF/2561/A/082/T_0001.PDF.

[44] Ministry of Education, "Policies and focuses of the Ministry of Education Fiscal year 2024," 2024, [Online]. Available: https://www.moe.go.th/360policy-and-focus-moe-fiscal-year-2024.
[45] U. Hanwong and P. Rupavijetra, "Plans and policy for new generation development in Thailand: expectation & beyond," *Fostering Excellent Next Generation*, 2022.
[46] Organization for Economic Cooperation and Development (OECD), "PISA 2018 assessment and analytical framework," 2019, [Online]. Available: https://www.oecd.org/education/pisa-2018-assessment-and-analytical-framework-b25efab8-en.htm.

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