Infinity Journal of Mathematics Education
Volume 12, No. 1, February 2023
https://doi.org/10.22460/infinity.v12i1.p69-84
p-ISSN 2089-6867
e–ISSN 2460-9285

DEVELOPING REALISTIC MATHEMATICS EDUCATION-BASED WORKSHEETS FOR IMPROVING STUDENTS' CRITICAL THINKING SKILLS

Reza Lestari[1], Rully Charitas Indra Prahmana[2*], Maureen Siew Fang Chong[3], Masitah Shahrill[4]
[1]STKIP Muhammadiyah Pagaralam, Indonesia
[2]Universitas Ahmad Dahlan, Indonesia
[3]Department of Educators Management, Ministry of Education, Brunei Darussalam
[4]Sultan Hassanal Bolkiah Institute of Education, Universiti Brunei Darussalam, Brunei Darussalam

Article Info

Article history:

Received July 15, 2022
Revised Dec 24, 2022
Accepted Feb 14, 2023

Keywords:

Critical Thinking Skills,
Realistic Mathematics Education,
Research and Development,
Student Worksheets

ABSTRACT

Applying critical thinking is an essential skill in the 21st century. However, teaching materials that do not facilitate students to improve these skills impact the achievement of learning objectives. Therefore, educators need appropriate teaching materials that encourage students to enhance their thinking skills. This study aims to develop teaching materials based on Realistic Mathematics Education (RME) to improve students' critical thinking skills. The development model used is ADDIE consisting of Analysis, Design, Development, Implementation, and Evaluation phases. The instruments used, consist of validated student worksheets based on material experts and media experts, pretest questions, posttest questions, and the practicality of student worksheets. The results showed that the student worksheets developed were feasible regarding validity, practicality, and effectiveness. The validity of the student worksheets is indicated by the average score of two material expert validators and two media expert validators, each of which is in the good and excellent categories. The practicality of the student worksheets is denoted by the average value of student assessments included in the practical category. Then its effectiveness is shown by increasing students' critical thinking skills after being given intervention using the student worksheets.

Corresponding Author:

Rully Charitas Indra Prahmana,
Department of Mathematics Education,
Universitas Ahmad Dahlan
Jl. Pramuka No. 42, Pandeyan, Umbulharjo, Daerah Istimewa Yogyakarta 55161, Indonesia.
Email: rully.indra@mpmat.uad.ac.id

How to Cite:

Lestari, R., Prahmana, R. C. I., Chong, M. S. F., & Shahrill, M. (2023). Developing realistic mathematics education-based worksheets for improving students' critical thinking skills. *Infinity*, *12*(1), 69-84.

1. INTRODUCTION

Critical thinking skills are higher-order thinking skills that are part of 21st century skills (Hujjatusnaini et al., 2022; Zetriuslita et al., 2018). Efforts to develop critical thinking skills have become the main goal in the mathematics education curriculum worldwide (Weng et al., 2022; Yildirim et al., 2011). Critical thinking skills are needed in the

development of students' thinking (Hsu et al., 2022; Mahanal et al., 2019) as it is one of the key skills needed in the 21st century. Critical thinking is the central pillar to preparing students in the 21st century at the education level (Koyunlu Ünlü & Dökme, 2022; Sulaiman et al., 2008). Thus, the ability to think critically is an essential basic ability possessed by students to obtain the truth from various problems.

Critical thinking skills are important for students to have and develop to deal with problems and everyday problems (Wang et al., 2022). Critical thinking skills make students careful in solving problems so that the resulting decisions become appropriate and reasonable solutions (Berestova et al., 2022). Critical thinking skills familiarize students with developing rational attitudes in determining the best alternative choices (Plummer et al., 2022). In addition, critical thinking allows students to study problems systematically, face challenges in an organized manner, formulate innovative questions, and design original solutions (Ramírez-Montoya et al., 2022; Sasson et al., 2022). Thus, the ability to think critically must be owned by students because it provides many benefits.

Critical thinking skills are the basis of the thinking process to analyze arguments and stimulate ideas on any meaning or other forms of interpretation to develop logical thinking patterns (Marzuki et al., 2021). It involves the ability to use prior knowledge to draw logical decisions from an issue, so that the truth that is considered the best solution can be done through scientific method steps (Ennis, 2011). Students' critical thinking skills need to be trained using contextual problems in everyday life (Shavelson et al., 2019; Yuliati et al., 2018). One of the causes of the low level of critical thinking is the application of teacher-centered learning, where students are passive recipients and do not have the opportunity to think (Khalid et al., 2020). Thus, critical thinking skills are fundamental for students to improve and develop in the mathematics learning process.

Realizing the importance of developing critical thinking skills, it is essential to have mathematics learning that involves more active students' participation and engagement in the learning process (Lugosi & Uribe, 2022). Critical thinking skills need to be stimulated and developed in the mathematics learning process (Hafni et al., 2019; Yumiati & Kusumah, 2019; Zetriuslita et al., 2018) because it is one of the skills needed in the 21st century. However, the facts in the field show that critical thinking-oriented learning is still lacking. This is evident by Indonesia's PISA results in 2018, which decreased compared to 2015 PISA results. For the mathematics category, Indonesia is ranked 7th from the bottom, 73rd out of 79 countries, with the score of 379 compared to the international average score of 459 (OECD, 2019). In this case, Indonesian students' critical thinking ability is still relatively low. Therefore, critical thinking skills are very important to be improved through learning models that involve learners playing an active role in the learning process.

Realistic Mathematics Education (henceforth, referred to as RME) based learning is one of the effective learning alternatives where mathematical concepts can be conveyed well (Prahmana et al., 2020; Risdiyanti & Prahmana, 2021). RME is a domain-specific instruction theory that focuses on problems that are "real" or that have been experienced by learners, emphasizes the skills of the process of doing mathematics, discussing, and collaborating, brainstorming with classmates, finding their mathematical concepts, and using mathematics to solve problems (van den Heuvel-Panhuizen & Drijvers, 2020). Realistic learning is not only related to the real-world context but also related to the emphasis on imagination so that the problems given in learning can be imagined by learners (Basuki & Wijaya, 2019; Zulkardi, 2002). The RME approach is suitable for middle school learners through the teaching materials provided, namely module, student worksheet, and learning trajectory (Risdiyanti & Prahmana, 2021). Learners did not see difficulties in working on teaching materials with RME approach. Therefore, with the help of teaching materials, the RME approach can be the best choice to facilitate learners in improving critical thinking skills.

Teaching materials are all forms of materials used to help teachers or instructors carry out teaching and learning activities in the classroom (de Jong et al., 2019). One of the teaching materials used in the school is the student worksheets. The student worksheets guide learners in understanding process skills and material concepts that will be studied (Dewi et al., 2023; Nurfadhillah et al., 2018). RME-based student worksheets can improve students' critical thinking skills (Samura et al., 2022; Susandi & Widyawati, 2022) and suitable for use and fall into the category of both and improved critical thinking skills of learners who use RME-based student worksheets as high (Sari & Putri, 2021). Therefore, we develop teaching materials, namely student worksheet, based on the RME approach that can improve students' critical thinking skills.

2. METHOD

This research is development research using the ADDIE model, which aims to develop valid, practical, and effective student worksheets. Five stages are applied to developing the student worksheets using the ADDIE model, including analysis, design, development, implementation, and evaluation (Branch, 2009). The analysis phase includes material, mathematics curriculum, student characteristics, and work plan analyses. Next is the design stage; the student worksheets are designed according to the results analysis that has been done, the required instruments, and the determination of the validator. At the same time, the preparation of student worksheets and validation are included in the development stage. The first author carried out several teaching and learning activities at the implementation stage, including a pretest, student worksheets trial, posttest, and assessment. Finally, the evaluation stage focuses on assessing the results of the analyses of validity, practicality, and effectiveness and making improvements to the student worksheets. Figure 1 illustrates the research procedure.

Figure 1. Research procedure

The population used in this study were seventh-grade students from one of private school in Pagaralam, Indonesia, which consisted of 10 classes. Furthermore, the selected

research sample was 26 students from Class VII 5, which would later be used as a large-scale trial class. As for the small-scale trial sample using 22 students of Class VII 2.

3. RESULT AND DISCUSSION

3.1. Stage of Analysis

The analysis stage is the initial stage before designing teaching materials. At this stage, curriculum analysis, analysis of learners' characteristics, material analysis, and work plan analysis so that the teaching materials can be developed based on the situation's needs.

3.1.1. Curriculum Analysis

Before reviewing the mathematics curriculum applied at this school, teachers were interviewed regarding the curriculum's implementation in schools. The interview results show that the curriculum used in all classes is the 2013 curriculum. Furthermore, assessing the set material in the 2013 curriculum and the extent to which the material is taught in class VII by the Core Competencies (CC) and Basic Competencies (BC) determined in the curriculum.

Teachers at this school use CC and BC knowledge and skills in the 2013 curriculum. Still, it is not fully implemented because the Competency Achievement Indicators (CAI) compiled by teachers are still not included. Based on the interview results, the CAI is prepared by the BC, which is entirely contained in the curriculum. The CAI indicates competence that students must achieve according to the curriculum sequence. The CAI compiled in this study are presented in Table 1.

Table 1. Curriculum analysis

Core Competencies (CC)	Basic Competence (BC)	Competency Achievement Indicator (CAI)
a. Understand knowledge (factual, conceptual, and procedural) based on his curiosity about science, technology, art, culture-related phenomena, and visible events. b. Try, process, and recite in the concrete realm (using, parsing, stringing, modifying, and creating) and the abstract realm (writing, reading, counting, drawing, and composing) according to those studied in the same school and other sources in the same point of view/ theory.	a. BC Knowledge: 3.4 Describes and states sets, subsets, universe sets, empty sets, and set complements using contextual problems. b. BC Knowledge: 3.5 Describes and performs binary operations on sets using contextual problems. c. BC Skills: 4.4 Solves contextual problems relating to sets, subsets, universe sets, empty sets, and set complements. d. BC Skills: 4.5 Resolves contextual problems related to binary operations on the set	a. States set and not set. b. Determines subsets, universe sets, empty sets, set complements c. Determines binary operations on a set d. Solves problems related to sets, subsets, universe sets, empty sets, set complements e. Resolves problems related to binary operations on the set

3.1.2. Material Analysis

The material analysis is based on the CC, BC, and CAI that has been prepared at the stage of competency analysis that students must achieve, then analyze what material will be contained in the student worksheets through collecting references related to material that is by the scope of BC. Subsequently, determine the content and main materials as well as sub-sections of the main material to be developed in the student worksheets as listed here: 1) understanding of the set; 2) stating members and not members of the set; 3) notation of the set; 4) determining the empty set, the set universe, subsets and Venn diagrams; and 5) define set operations.

3.1.3. Analysis of Characteristics of Learners and Work Plan Analysis

At this stage, interviews were conducted with mathematics teachers at this school regarding students' initial knowledge, prerequisite materials and subject matter on sets, difficulties encountered in learning, and written tests to determine the critical thinking skills of students who will become student worksheet users. According to the teacher, the interview results showed that the student's critical thinking ability was still low. The teacher said that students had difficulties in understanding the questions, namely in the form of students being able to read all the words in the questions but not understanding or understanding the overall meaning of the words in the questions. Students cannot write down what is known and what is being asked of the question. In stating the set and registering the members of the stage, students have difficulty writing down what is known and what the question is asking. Students are still glued to the teacher's explanation and have not been able to identify ideas and arguments, perform calculations and draw conclusions. Whereas, work plan analysis consists of seven phases: set development goals, design student worksheets, develop student worksheets validation instruments, perform validation, test the validity of student worksheets, implement, test the practicality and effectiveness of student worksheets, and evaluation.

3.2. Design Stage

In the design stage, the student worksheets are designed according to the analysis results that have been done. The developed student worksheets contain set material for Class VII and RME characteristics. The first and second authors design the presentation of materials that have elements of RME which include the introduction of concepts through problems to learners, organizing learners to research, group investigation assistance, development and presentation of interpretation and problem solving of learners, as well as the analysis and assessment of the process and results of solving learners' problems. The characteristic content design of RME in student worksheets is designed as a strategy to align materials and improve learners' critical thinking skills. The design stage is done by selecting symbols as icons to distinguish between RME characteristics and indicators of critical thinking skills.

In addition to the student worksheets design, at this stage, also prepared the design of critical thinking test instruments in the form of pretest and posttest questions, as well as various instrument designs needed in the development of student worksheets, including student worksheets validation sheets by material experts, student worksheets validation sheets by media experts, and student worksheets assessment sheets by learners. At this stage also began to determine the candidate's validator. There are six validator candidates have

been determined in this study. The details of each prospective validator can be seen in Table 2.

Table 2. List of validators

Validator	Information
Validator 1	Validation of material expert Instruments (student worksheets validation sheet by a material expert)
	Validation of media expert instruments (student worksheets validation sheet by media expert)
	Validation of participant response instruments (student worksheets assessment sheet by learners)
Validator 2	Validation of critical thinking test instruments (Pretest Problem)
	Validation of critical thinking test instruments (Posttest Problem)
Validator 3	Validation of student worksheets as a media expert
Validator 4	Validation of student worksheets as a media expert
Validator 5	Validation of student worksheets as a material expert
Validator 6	Validation of student worksheets as a material expert

3.3. Development Stage

The development stage involves the activity of translating design specifications at the design stage into physical form. This activity produces a prototype development product in the form of student worksheets based on RME to improve the ability to think critically of set materials; in addition to developing products, material expert validity instruments are also developed, including instruments for the expert media validity, learners' response questionnaire, pretest and posttest critical thinking skills. After each instrument is declared fit for use, the next step is to prove its validity. The validity of student worksheet products is measured using validated instruments, namely questionnaire. Evaluation of the validity of student worksheets by material experts is contained in Table 3.

Table 3. Recapitulation of student worksheets validity by materials expert

Validator	Total Score	Category
Validator 5	60	Good
Validator 6	61	Good
The total score of the two validators		121
Average		60.5
Validity Category		Valid

Evaluation of the validity of student worksheets products by Media Experts is contained in Table 4.

Table 4. Recapitulation of student worksheets validity by media experts

Validator	Total Score	Category
Validator 3	122	Good
Validator 4	134	Excellent
The total score of the two validators		256
Average		128
Validity Category		Highly Valid

Table 3 shows that the average score of both validator expert materials indicates that student worksheet products fall into the valid category. Table 4 shows that the average value of both media expert validators indicates that student worksheet products fall into the category of highly valid, so student worksheet products have been valid and worthy of the aspects of material experts and media experts. In contrast, the results of media expert validation in giving comments or suggestions can be seen in Table 5.

Table 5. Comments or suggestions from media experts

Validator	Comments/Suggestions
Validator 3	Add the back cover of the student worksheets.
	In the instructions for using student worksheets, it would be nice to explain every symbol. For example, in the use of context, what does it mean? What should learners do in the use of this context?
	In the concept map section, it is seen that the set material consists of knowing the set and the operation of the set. For the empty set and so on, there is no concept map from where and where? The builder needs to create a concept map that is easier to understand.
Validator 4	The back cover does not exist.
	Spacing between text raised at least 1.5 spaces.
	On page 7 of the 2021 calendar image should be brought up.

After validating the product, improvements were made based on material and media experts' comments and suggestions. Some of the improvements can be seen in the following image. The student worksheet back cover was added according to comments and suggestions from experts, as shown in Figure 2.

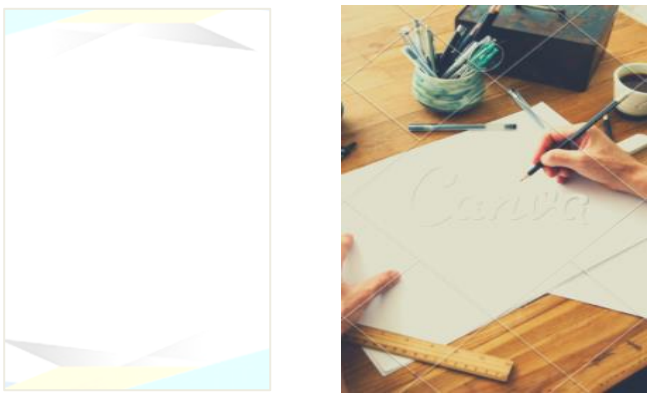

Figure 2. Before revision (left image) and after revision (right image)

In the instructions for using the student worksheets, each symbol is explained according to the validator's input. Furthermore, improvements were made to the concept map section to make it easier for learners to understand.

3.4. Implementation Stage

The student worksheets validated and declared eligible for use by the validator can be tested in large-scale or experimental classes. However, before being tested in a large-scale class, the student worksheets were first tested in a small-scale class, namely on 22 randomly selected students. After carrying out teaching and learning activities using student worksheets, they filled out student response questionnaires to assess the practicality of student worksheets, which material experts and media experts had previously validated. After implementing a small-scale class trial and then applying it to a large-scale class with 26 students, all activities carried out by students during learning are centered on student worksheets. The following are the details of the implementation activities in large-scale classes.

3.4.1. First Meeting Activities

The first meeting was held on Thursday, July 29, 2021. At the first meeting, students were given pretest questions. Pretest questions were used to determine the material for the initial set of students before learning using the student worksheets. The pretest questions consist of three description questions with a time allocation of 80 minutes.

3.4.2. Second Meeting Activities

The second meeting was held on Monday, August 2, 2021. The student worksheets were introduced to the students, formed several groups, explained instructions for using the student worksheets, and then students studied the preliminary material. The activities of the second meeting can be seen in Figure 3.

Figure 3. Activities of the second meeting

3.4.3. Third Meeting Activities

The third meeting was held on Thursday, August 5, 2021. All Class VII 5 students started learning using the student worksheets at this meeting. The first and second authors guide and supervise students in this learning process. We engage students through Student Worksheets and students study activity sheet 1, which contains set material that is given realistic problems about several menus in the school canteen.

3.4.4. Fourth Meeting Activities

The fourth meeting was held on Monday, August 9, 2021. At this meeting, students continued learning using Student Worksheets, namely studying activity sheet 2, which contains set material given realistic problems. Students pay attention to a calendar included in Student Worksheets, then follow the steps consisting of the use of context, use of models, use of learner construction, interactivity, and linkage. They said that learning sets using Student Worksheets equipped with steps to solve each problem made it easier to understand the set material. Student activities at this meeting can be seen in Figure 4.

Figure 4. Activities of the fourth meeting

3.4.5. Fifth Meeting Activities

The fifth meeting was held on Thursday, August 12, 2021. At this meeting, students resumed learning using student worksheets, namely studying activity sheet 3, which contains set material given realistic problems about various kinds of empek-empek (a type of Indonesian snack), with the aim that students can solve contextual problems related to set operations. This student worksheet is equipped with steps from the characteristics of RME, and the objective is to train students to develop their thinking skills.

3.4.6. Sixth Meeting Activities

The sixth meeting was held on Monday, August 16, 2021. At this meeting, students were given posttest questions. Posttest questions are used to see student learning outcomes after using student worksheets. The posttest questions consist of three description questions

with a time allocation of 80 minutes. Student activities working on posttest questions can be seen in Figure 5.

Figure 5. Students working on posttest questions

3.5. Evaluation Stage

In the evaluation stage, it is done by comparing the value of the results of critical thinking ability tests in the form of pretest that have been validated in the experimental class with the value of the critical thinking ability test results in the form of posttest that have also been validated in the experimental class. The first author gave the product to the experimental class before giving a posttest problem to the experimental class. The comparison between the pretest and posttest values is used to see the effectiveness of the use of the product in improving the ability to think critically in the set material.

3.6. Discussion

This research was conducted using the ADDIE model in developing student worksheets based on Realistic Mathematics Education, which is used to improve students' critical thinking skills in learning a set. Risdiyanti and Prahmana (2021) designed a learning trajectory set using RME with Indonesian shadow puppets and Mahabharata stories as a learning context. It means that RME can be used as a learning approach in teaching the learning of a set. The developed student worksheets have undergone several phases to obtain valid, practical, and effective criteria.

The ADDIE model is divided into five stages: analysis, design, development, implementation, and evaluation (Peterson, 2003). In the initial stage, namely analysis, the researcher analyzed the school's needs as a reference for developing products. Needs analysis includes an analysis of the competencies students must achieve, material analysis, and student characteristics that consistently show that students need worksheet teaching materials that can improve the ability to think critically about a set. It is known that when students are given math problems and the results of their work when examined from indicators of critical thinking skills, most students have yet to be able to determine what is known or do analysis, evaluation, and conclusions. Because of these conditions, the researchers start to think about finding solutions to these problems. One is by developing teaching materials in the form of student worksheets based on realistic mathematics education with the hope that students would find it easier to learn set material and be more active in the learning process (Prahmana et al., 2020). Before researchers develop students'

worksheets based on realistic mathematics education, researchers determine the critical thinking skills students possess through pre-test and post-test questions. Expert validators have validated the pre-test and post-test questions, then tested on students who have received set material to test the validity and reliability.

Furthermore, the researcher carried out the product design stage. At this stage, the researcher designed the student worksheet according to the needs analysis (Spatioti et al., 2022). This worksheet is designed based on facts in the field that students need, which makes the problem as a starting point and can improve students' critical thinking skills. At this stage, the researcher made a concept map of the student worksheet presentation, determined the format, and made learning stages in the student worksheet based on Realistic Mathematics Education to improve students' critical thinking skills.

In the development stage, the first activities were the content and media expert validation tests (Davis, 2013). The content expert validation test results obtained an average rating of two validators 60.5 in the good category and an average rating of two media expert validators, 128 in the very good category. The acquisition of this value indicates that the developed student worksheet is content and media valid. A student worksheet is said to be valid if the average score of the validity assessment meets the minimum standards of good (Mulbar & Zaki, 2018).

At the implementation stage, the activities carried out were the implementation of student worksheets in small classes, and then a small class practicality test was carried out. The small class practicality test results obtained an average rating of 77.8 with the Good rating criterion, so the student worksheets prepared are practically used in small classes. Then the student worksheets are applied to the large or experimental class, and a significant class practicality test is carried out. The large class practicality test results obtained an average rating of 80.07 with the good rating criterion, so the student worksheets prepared are practically used in large classes. The student worksheets are practical if the average practicality assessment score meets the minimum standards of good (Hasibuan et al., 2019).

The final stage is the evaluation stage. This stage determines the effectiveness of student worksheets based on Realistic Mathematics Education on students' critical thinking skills. The researchers gave the post-test to the students and then analyzed it to obtain data on the effectiveness of the student worksheets.

Student worksheets' effectiveness data were obtained from the results of the experimental class post-test scores. The technique used by researchers to test effectiveness is comparing students' critical thinking skills test results in the form of pre-test questions. Students did it before being given student worksheets based on Realistic Mathematics Education developed with the results of critical thinking ability tests in the form of post-test questions after being given a Realistic Mathematics Education-based student worksheets developed. At this stage, to compare the results of the critical thinking ability test in the form of pre-test questions and the results of the critical thinking ability test in the form of post-test questions, the researcher conducted a paired sample t-test.

The paired sample t-test shows that the value of Sig. (2-tailed) is $0.000 < 0.05$, so a significant difference exists between the results of learning mathematics in the pre-test and post-test data. The average pre-test score obtained by students is 37.31, while the average post-test score obtained by students is 67.50. The N-Gain value is 0.48, so the increase is included in the moderate category when viewed from the ability to think critically. Therefore, based on the data obtained, student worksheet is effective in terms of students' critical thinking skills. In other words, there was an increase between the results of the critical thinking ability test in the form of pre-test questions before being given learning materials in the form of a Realistic Mathematics Education-based student worksheet and the results of the critical thinking ability test in the form of post-test questions after being given

learning materials in the form of Realistic Mathematics Education-based student worksheet. It aligns with the results of Erita et al. (2022) research that learning using a Realistic Mathematics Education-based student worksheet can improve students' critical thinking skills. It means there is an increase in the critical thinking skills in the experimental class before teaching materials in the form of student worksheets based on Realistic Mathematics Education and after being given teaching materials in the form of student worksheets based on Realistic Mathematics Education (Hasibuan et al., 2019). They can also use the developed student worksheet with these results because it meets the product eligibility requirements: valid, practical, and effective. It shows that student worksheets based on Realistic Mathematics Education can improve students' critical thinking skills. The results of this study indicate that the characteristics of Realistic Mathematics Education contained in the Realistic Mathematics Education approach theoretically have elements that can grow indicators included in critical thinking skills. This happens because Realistic Mathematics Education brings students to real-world experiences daily so that mathematics lessons are not separated from students' daily lives (Prahmana et al., 2020; Samura et al., 2022; Susandi & Widyawati, 2022; Zetriuslita et al., 2018).

This research aligns with development research conducted by Wewe and Juliawan (2019) that Realistic Mathematics Education-based worksheets to improve critical thinking skills meet good criteria and are suitable for use as alternative mathematics teaching materials (Basuki & Wijaya, 2019). Therefore the results of this study add to empirical evidence, which states that the Realistic Mathematics Education approach implemented in student worksheets can improve students' critical thinking skills.

4. CONCLUSION

Students can use these worksheets based on RME to improve their critical thinking skills because of their validity, practicality, and effective criteria. The RME-based student worksheets met the valid criteria. It is measured by assessing material experts, who obtained an average score of 60.5 with a good category, and assessments from media experts with a score of 128 with excellent types. The student worksheets met the practical criteria based on the learner's response questionnaire assessment, with an assessment score of 80.07 and a maximum score of 100. The student worksheets developed based on RME on quality critical thinking skills judged by effectiveness. There was a significant difference between the pre-test and post-test scores for critical thinking skills. The average post-test score is greater than the average pre-test score, which shows an increase in the moderate category between the pre-test and post-test scores. Therefore, the student worksheets meet the effective criteria. The findings of this study also emphasize the effect of developing teaching materials based on RME to improve students' critical thinking skills with positive outcomes.

ACKNOWLEDGEMENTS

The authors thank Chika Rahayu, M.Pd., and Meryansumayeka, S.Pd, M.Sc., as experts in validating our e-module focusing on the content. Furthermore, we thank Dr. Sri Adi Widodo, M.Pd., and Dr. Bambang Riyanto, M.Pd., as the expert to validate our e-module focusing on the media. We also would like to thank Anggit Prabowo, M.Pd., and Indah Widyaningrum, M.Pd. as the expert to validate the research instrument for this research. Lastly, we thank Universitas Ahmad Dahlan and SMP Muhammadiyah Pagaralam for providing facilities and opportunities to develop and carry out this research.

REFERENCES

Basuki, W. A., & Wijaya, A. (2019). Students worksheet based on realistic mathematics education: How the effect toward reasoning ability? *Journal of Physics: Conference Series*, *1157*(2), 022130. https://doi.org/10.1088/1742-6596/1157/2/022130

Berestova, A., Kolosov, S., Tsvetkova, M., & Grib, E. (2022). Academic motivation as a predictor of the development of critical thinking in students. *Journal of Applied Research in Higher Education*, *14*(3), 1041-1054. https://doi.org/10.1108/JARHE-02-2021-0081

Branch, R. M. (2009). *Instructional design: The ADDIE approach* (Vol. 722). New York: Springer. https://doi.org/10.1007/978-0-387-09506-6

Davis, A. L. (2013). Using instructional design principles to develop effective information literacy instruction: The ADDIE model. *College & Research Libraries News*, *74*(4), 205-207. https://doi.org/10.5860/crln.74.4.8934

de Jong, L., Meirink, J., & Admiraal, W. (2019). School-based teacher collaboration: Different learning opportunities across various contexts. *Teaching and Teacher Education*, *86*, 102925. https://doi.org/10.1016/j.tate.2019.102925

Dewi, A. K., Slamet, S. Y., Atmojo, I. R. W., & Syawaludin, A. (2023). The influence of interactive digital worksheets based on level of inquiry towards science process skills in elementary school. *Pegem Journal of Education and Instruction*, *13*(1), 251-258. https://doi.org/10.47750/pegegog.13.01.27

Ennis, R. (2011). Critical thinking: Reflection and perspective Part II. *Inquiry: Critical thinking across the Disciplines*, *26*(2), 5-19. https://doi.org/10.5840/inquiryctnews201126215

Erita, S., Utami, E. S. D., & Ningsih, F. (2022). Realistic mathematic education-based student worksheet to improve students' mathematical reasoning on circle material. *Indonesian Journal of Science and Mathematics Education*, *5*(2), 210-223. https://doi.org/10.24042/ijsme.v5i2.11249

Hafni, R. N., Sari, D. M., & Nurlaelah, E. (2019). Analyzing the effect of students' habits of mind to mathematical critical thinking skill. *Journal of Physics: Conference Series*, *1211*(1), 012074. https://doi.org/10.1088/1742-6596/1211/1/012074

Hasibuan, A. M., Saragih, S., & Amry, Z. (2019). Development of learning materials based on realistic mathematics education to improve problem solving ability and student learning independence. *International Electronic Journal of Mathematics Education*, *14*(1), 243-252. https://doi.org/10.29333/iejme/4000

Hsu, F.-H., Lin, I. H., Yeh, H.-C., & Chen, N.-S. (2022). Effect of socratic reflection prompts via video-based learning system on elementary school students' critical thinking skills. *Computers & Education*, *183*, 104497. https://doi.org/10.1016/j.compedu.2022.104497

Hujjatusnaini, N., Corebima, A., Prawiro, S., & Gofur, A. (2022). The effect of blended project-based learning integrated with 21st-century skills on pre-service biology teachers' higher-order thinking skills. *Jurnal Pendidikan IPA Indonesia*, *11*(1), 104-118. https://doi.org/10.15294/jpii.v11i1.27148

Khalid, M., Saad, S., Hamid, S. R. A., Abdullah, M. R., Ibrahim, H., & Shahrill, M. (2020). Enhancing creativity and problem solving skills through creative problem solving in

teaching mathematics. *Creativity Studies*, *13*(2), 270-291. https://doi.org/10.3846/cs.2020.11027

Koyunlu Ünlü, Z., & Dökme, İ. (2022). A systematic review of 5E model in science education: proposing a skill-based STEM instructional model within the 21-st century skills. *International Journal of Science Education*, *44*(13), 2110-2130. https://doi.org/10.1080/09500693.2022.2114031

Lugosi, E., & Uribe, G. (2022). Active learning strategies with positive effects on students' achievements in undergraduate mathematics education. *International Journal of Mathematical Education in Science and Technology*, *53*(2), 403-424. https://doi.org/10.1080/0020739X.2020.1773555

Mahanal, S., Zubaidah, S., Sumiati, I. D., Sari, T. M., & Ismirawati, N. (2019). RICOSRE: A learning model to develop critical thinking skills for students with different academic abilities. *International Journal of Instruction*, *12*(2), 417-434. https://doi.org/10.29333/iji.2019.12227a

Marzuki, M., Wahyudin, W., Cahya, E., & Juandi, D. (2021). Students' critical thinking skills in solving mathematical problems; A systematic procedure of grounded theory study. *International Journal of Instruction*, *14*(4), 529-548. https://doi.org/10.29333/iji.2021.14431a

Mulbar, U., & Zaki, A. (2018). Design of realistic mathematics education on elementary school students. *Journal of Physics: Conference Series*, *1028*(1), 012155. https://doi.org/10.1088/1742-6596/1028/1/012155

Nurfadhillah, N., Johar, R., & Ahmad, A. (2018). The quality of learning materials through mathematics reaslitic to improve students' mathematical communication ability in the elementary school. *Journal of Physics: Conference Series*, *1088*(1), 012077. https://doi.org/10.1088/1742-6596/1088/1/012077

OECD. (2019). *PISA 2018 Results (Volume I): What students know and can do*. Paris: OECD Publishing.

Peterson, C. (2003). Bringing ADDIE to life: Instructional design at its best. *Journal of Educational Multimedia and Hypermedia*, *12*(3), 227-241.

Plummer, K. J., Kebritchi, M., Leary, H. M., & Halverson, D. M. (2022). Enhancing critical thinking skills through decision-based learning. *Innovative Higher Education*, *47*(4), 711-734. https://doi.org/10.1007/s10755-022-09595-9

Prahmana, R. C. I., Sagita, L., Hidayat, W., & Utami, N. W. (2020). Two decades of realistic mathematics education research in Indonesia: A survey. *Infinity Journal*, *9*(2), 223-246. https://doi.org/10.22460/infinity.v9i2.p223-246

Ramírez-Montoya, M. S., Castillo-Martínez, I. M., Sanabria-Z, J., & Miranda, J. (2022). Complex thinking in the framework of education 4.0 and open innovation-A systematic literature review. *Journal of Open Innovation: Technology, Market, and Complexity*, *8*(1), 4. https://doi.org/10.3390/joitmc8010004

Risdiyanti, I., & Prahmana, R. C. I. (2021). Designing learning trajectory of set through the Indonesian shadow puppets and Mahabharata stories. *Infinity Journal*, *10*(2), 331-348. https://doi.org/10.22460/infinity.v10i2.p331-348

Samura, A. O., Darhim, D., Juandi, D., Said, A. M., Nani, K. L., & Tamur, M. (2022). Improving the critical thinking ability of junior high school students through realistic

mathematics education innovation. *AIP Conference Proceedings*, *2577*(1), 020057. https://doi.org/10.1063/5.0096077

Sari, E. M., & Putri, R. I. I. (2021). Project-based worksheets using a lesson study system. *Infinity Journal*, *10*(1), 41-52. https://doi.org/10.22460/infinity.v10i1.p41-52

Sasson, I., Yehuda, I., Miedijensky, S., & Malkinson, N. (2022). Designing new learning environments: An innovative pedagogical perspective. *The Curriculum Journal*, *33*(1), 61-81. https://doi.org/10.1002/curj.125

Shavelson, R. J., Zlatkin-Troitschanskaia, O., Beck, K., Schmidt, S., & Marino, J. P. (2019). Assessment of university students' critical thinking: Next generation performance assessment. *International Journal of Testing*, *19*(4), 337-362. https://doi.org/10.1080/15305058.2018.1543309

Spatioti, A. G., Kazanidis, I., & Pange, J. (2022). A comparative study of the ADDIE instructional design model in distance education. *Information*, *13*(9), 402. https://doi.org/10.3390/info13090402

Sulaiman, W. S. W., Rahman, W. R. A., & Dzulkifli, M. A. (2008). Relationship between critical thinking dispositions, perceptions towards teacher, learning approaches and critical thinking skills among university students. *The Journal of Behavioral Science*, *3*(1), 122-133.

Susandi, A. D., & Widyawati, S. (2022). Implementation of realistic mathematic education (RME) learning model in improving critical thinking skills. *Al-Jabar: Jurnal Pendidikan Matematika*, *13*(2), 251-260.

van den Heuvel-Panhuizen, M., & Drijvers, P. (2020). Realistic Mathematics Education. In S. Lerman (Ed.), *Encyclopedia of mathematics education* (pp. 713-717). Springer International Publishing. https://doi.org/10.1007/978-3-030-15789-0_170

Wang, D., Liu, H., & Hau, K.-T. (2022). Automated and interactive game-based assessment of critical thinking. *Education and Information Technologies*, *27*(4), 4553-4575. https://doi.org/10.1007/s10639-021-10777-9

Weng, X., Cui, Z., Ng, O.-L., Jong, M. S. Y., & Chiu, T. K. F. (2022). Characterizing students' 4C skills development during problem-based digital making. *Journal of Science Education and Technology*, *31*(3), 372-385. https://doi.org/10.1007/s10956-022-09961-4

Wewe, M., & Juliawan, I. W. (2019). Developing mathematical devices with characteristics realistic mathematics education. *Al-Jabar: Jurnal Pendidikan Matematika*, *10*(1), 1-10. https://doi.org/10.24042/ajpm.v10i1.3884

Yildirim, B., Özkahraman, S., & Karabudak, S. S. (2011). The critical thinking teaching methods in nursing students. *International Journal of Business and Social Science*, *2*(24).

Yuliati, L., Fauziah, R., & Hidayat, A. (2018). Student's critical thinking skills in authentic problem based learning. *Journal of Physics: Conference Series*, *1013*(1), 012025. https://doi.org/10.1088/1742-6596/1013/1/012025

Yumiati, Y., & Kusumah, Y. S. (2019). Interaction between Students' Learning and Early Mathematical Skills to Increase Mathematical Critical Thinking Skills. *Al-Jabar: Jurnal Pendidikan Matematika*, *10*(1), 125-134. https://doi.org/10.24042/ajpm.v10i1.3712

Zetriuslita, Z., Wahyudin, W., & Dahlan, J. A. (2018). Association among mathematical critical thinking skill, communication, and curiosity attitude as the impact of problem-based learning and cognitive conflict strategy (PBLCCS) in number theory course. *Infinity Journal*, *7*(1), 15-24. https://doi.org/10.22460/infinity.v7i1.p15-24

Zulkardi, Z. (2002). *Developing a learning environment on realistic mathematics education for Indonesian student teachers*. Doctoral dissertation. Enschede: University of Twente. Retrieved from https://repository.unsri.ac.id/871