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Improving Students' Metacognition Skills through Mathematics Learning Based on Realistic Mathematics Education

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Abstrak

Metakognisi sangat penting namun dalam realitanya belum sesuai dengan yang diharapkan. Tujuan penelitian ini untuk menghasilkan modul pembelajaran yang valid, praktis, dan efektif serta untuk mengetahui metakognisi siswa pada materi Aljabar menggunakan modul matematika berbasis Realistic Mathematics Education (RME) yang telah dikembangkan. Penelitian ini menggunakan metode penelitian R&D (Research and Development). Partisipan pada penelitian ini adalah 2 kelas pada sekolah menengah pertama (SMP) dimana masing-masing kelas akan menjadi kelas eksperimen dan kelas kontrol. Subjek yang digunakan pada kelas eksperimen sebanyak 31 orang dan subjek pada kelas kontrol sebanyak 32 orang. Penelitian pengembangan pada penelitian ini menggunakan model Four-D (4D) yang memiliki empat tahapan meliputi pendefinisian, perancangan, pengembangan, dan penyebaran. Hasil penelitian ini menunjukkan bahwa modul matematika yang dikembangkan valid, praktis, dan efektif serta siswa yang menggunakan modul matematika berbasis RME mempunyai metakognisi lebih baik daripada siswa yang menggunakan buku teks matematika yang disediakan oleh sekolah. Temuan dari penelitian ini dapat dijadikan landasan dalam merancang bahan ajar yang relevan.
Kata Kunci: Aljabar; Matematika; Metakognisi; Realistic Mathematics Education.

Abstract

Metacognition is very important, but in reality, it is not in accordance with expectations. The purpose of this research is to produce valid, practical, and effective learning modules and to determine students' metacognition in Algebra material using the *Realistic Mathematics Education* (RME)-based mathematics module that has been developed. This research uses the R&D (*Research and Development)* research method. Participants in this study are 2 classes in junior high school (SMP) where each class will be an experimental class and a control class. The subjects used in the experimental class were 31 people and the subjects in the control class were 32 people. The development research in this study uses the Four-D (4D) model which has four stages including definition, design, development, and deployment. The results of this study show that the mathematics modules developed are valid, practical, and effective and students who use RME-based mathematics modules have better metacognition than students who use mathematics textbooks provided by schools. The findings of this study can be used as a basis for designing relevant teaching materials.
Keywords: Aljabar; Mathematics; Metacognition; Realistic Mathematics Education.

I. Introduction

The many problems in the world of education in Indonesia is one of the reasons to improve the quality of mathematics education in schools. The problems faced in mathematics education are low student interest in mathematics learning and low student learning achievement. One of the things that affects is the thinking process of students' metacognition. According to Ormond (in Chairini, 2016) Metacognition is a person's understanding and belief in their cognitive processes, as well as a conscious effort to engage in the process of thinking and acting, aiming to improve learning and memory. Schraw (2020) emphasizes the importance of metacognition in education, where it is defined as an individual's awareness of their own thinking process and the ability to manage and regulate the way of learning. Metacognition allows students to improve their learning strategies through self-evaluation and monitoring. According to Winne and Hadwin, metacognition involves self-assessment of learning abilities and the ability to monitor and adjust learning strategies. Metacognition is a verb that indicates a process while metacognition is an adjective that indicates activity by presenting the properties of metacognition. Metacognitive abilities can be used to predict academic achievement and high-level cognitive abilities. Students who have a strong self-awareness of their learning process will find it easier to set effective learning strategies.

Student metacognition is very important, but in reality, it is not in accordance with expectations. According to Williams and Atkins (in Rukminingrum, *et al*, 2017) said that the importance of metacognition is to help students carry out many of their learning tasks effectively. Metacognition is essential to achieve self-learning and self-regulation in the context of modern education (Winne & Hadwin, 2013). This reality is shown from PISA (*Programme for International Student Assessment*) data released by the OECD (*Organisation for Economic Co-operation and Development*) which evaluates the education system in the fields of mathematics, science, and reading. The results of the 2018 PISA study from 77 PISA participating countries around the world, show that the ability of Indonesian students in mathematics has an average score of 379 with an OECD average score of 487 (Ministry of Education and Culture, 2019). This score has decreased compared to 2015 where the average score in mathematics reached 386. Indonesia has experienced a decline in ranking, ranking 72 out of 77 countries (Fazzilah, Effendi, & Marlina, 2020). This is supported by data on the results of the Computer-Based National Examination (UNBK) at one of the junior high schools in Sragen Regency in 2019 announced by the Ministry of Education and Culture that the lowest average score was in mathematics, which was 44.73 (Center for Educational Research, 2019).

One of the materials in mathematics learning that is still a problem for some students is algebra. This is because of the distribution of algebra material that is always found at every grade level in high school. Algebra is a mathematical language that deals with variables, operations, and numbers that are interrelated. According to Lang, algebra involves the study of numbers, variables, and relationships through mathematical operations such as addition, multiplication, and division, which are extended into more abstract theories (Lang, 2017). The basic idea of algebra has an important position in mathematics, algebra is referred to as the lifeblood of mathematics (Maulana in Nurcholifah, 2021). In addition, according to James Stewart (2015), algebra is very important in studying calculus, which is one of the basic mathematical topics in engineering and physical sciences. Without a strong understanding of algebra, it is difficult to understand calculus concepts, such as differentiation and integration, which require symbolic manipulation and an understanding of mathematical functions. In the field of technology and computer science, I. Goodfellow et al., (2016) stated that linear algebra is one of the theoretical bases used in the development of computer algorithms and machine learning (machine learning). Algebra is used in data processing, pattern analysis, and calculations that allow the development of artificial intelligence.

At the junior high school level, algebra is included in the material tested in the National Examination (UN). Based on the UN results for the 2018/2019 school year in Sragen Regency, algebra material has a relatively low absorption capacity of 55.63. Absorption contains information on the proportion or presentation of correct answers selected based on the group or the Graduation Competency Standard (SKL).

Based on the results of the metacognition knowledge questionnaire and metacognition setting questions on 31 grade VII students, it was obtained: 1) in the aspect of declarative knowledge, 81% of students understood the topic or material of interest better, 52% of students still had difficulty understanding mathematical material; 2) in the aspect of procedural knowledge, 70% of students still use monotonous learning methods, 63% of students only learn when they experience difficulties, 81% of students are only silent when completing group assignments, 68% of students are still embarrassed to ask questions to teachers when they have difficulties in learning mathematics; 3) in the aspect of conditional knowledge, 72% of students do not understand a topic or subject matter well if they use pictures or diagrams, 53% of students pay attention to the teacher without knowing what the teacher has conveyed; 4) in the planning aspect, most students already know the information in the questions and problems asked in the questions; 5) in the monitoring aspect, only 2% of students understand how to solve problems such as the information applied to the solution is known, asked, and in the solution steps; 6) in the *evaluation* aspect, students cannot conclude from the results of their completion and some students do not answer the questions.

Given the existing problems, teaching materials are needed that are able to improve students' metacognitive abilities, facilitate understanding of subject matter, and apply their knowledge effectively. Teaching materials that can be developed to meet these needs are modules. The module is a complete unit, consisting of a series of learning activities, which have clearly provided effective learning results in achieving goals that have been formulated clearly and specifically (Suyosubroto in Syafri, 2018). Modules can be arranged based on the needs in the field. The researcher wants to develop a mathematics module based on *Realistic Mathematic Education* (RME), which is a teaching material in the form of print media in the field of mathematics and is systematically arranged by involving real problems to gain new knowledge in its use without guidance from teachers and aims to improve students' metacognition.

Based on these descriptions, an alternative solution that can solve the problems that have been described previously is to use a mathematics module based on *Realistic Mathematic Education* (RME) in Algebra material to support the learning process with the aim of improving the metacognition of grade VII students. The purpose of the research in this development is to determine the validity, practicality, and effectiveness of the *Realistic Mathematic Education* (RME)-based mathematics module on Algebra material with the aim of improving the metacognition of grade VII students and to find out whether students' metacognition on Algebra material uses Realistic Mathematic Education-based mathematics modules (RME) that has been developed better than the one that uses the mathematics textbook used in schools.

II. Method

The method used in this study is research and development or commonly referred to as R&D (*Research and Development*). Development research in education as a process of developing new educational products and testing their effectiveness through comparison with existing products (Budiyono, 2017). This study adopts the *Four-D* (4D) development model introduced by Thiagarajan, *et., al.* (1974). The research model includes four stages, namely define, *design*, *develop*, and *disseminate*. This research was conducted from April 2023 – February 2024 at SMPN. The subject of this study is junior high school grade VII students consisting of 2 randomly selected classes where each class will be an experimental class and a control class. A total of 31 students became research subjects in the experimental class and 32 students became research subjects in the control class.

This study uses the *Research and Development* (R&D) method with the *Four-D* (4D) model from Thiagarajan. The model includes four stages: definition, design, development, and deployment. 1) Definition, this stage involves needs analysis, task analysis, concept analysis, and student analysis. The focus is on understanding the characteristics of students and their needs in learning algebra. The results of the analysis show that students have difficulty understanding algebraic concepts and need more contextual teaching materials. 2) design, at this stage, designed a prototype of RME-based modules. This module includes various components such as learning objectives, learning materials, and evaluations tailored to the characteristics of students. Modules are designed to facilitate independent and interactive learning. 3) Development, module prototypes are validated by material, media, and language experts. This validation is to ensure that the modules are in accordance with the educational standards and needs of the students. After validation, the module is tested on a limited scale to measure its practicality and effectiveness. 4) Deployment, the last stage is the deployment of modules that have been refined based on the results of the trial. This module is then used in learning in junior high school.

Data analysis of the results of expert validation and practicality tests (teacher and student response questionnaires) on *the likert scale* using the Benchmark Reference Assessment (PAP) according to Budiyono (2020), namely the statement score divided by the number of statement items. Then the conversion of four assessment categories was carried out, namely an average score of 1.00 ≤ $\bar{X}$ < 1.75 with a poor category, an average score of 1.00 ≤ $\bar{X}$ < 1.75 with a fairly good category, an average score of 2.50 ≤ $\bar{X}$ < 3.25 with a good category, and an average score of 3.25 ≤ ≤ 4.00 with a very good category. $\bar{X}$

The analysis of module effectiveness test data was carried out in experimental research using *a Before-After Design* design with one group. The statistical analysis in this experimental study used a multivariate t-test for paired samples. This is because metacognition consists of two main components, namely metacognitive knowledge related to understanding the cognitive process itself, and metacognitive regulation related to the ability to control and regulate the cognitive process. Metacognitive knowledge was measured using questionnaires while metacognitive settings were measured using test questions.

Product efficacy test data was analyzed using a multivariate mean difference *t-test*. The population of the product efficacy test is grading VII junior high school students. The sample was taken randomly from 7 classes that had been simple *random sampling*. Each class will be used as an experimental class and a control class. Before the efficacy test is carried out, the product must meet normal and homogeneous requirements. If these two conditions are met, then the product efficacy test can be carried out.

III. Result and Discussion

The results of this study are described based on the development of RME-based modules that are piloted in grade VII. The development of this module uses a 4D model (*Define*, *Design*, *Develop*, *Disseminate).* The following will describe the 4D stages.

First, the define stage is carried out: a) the final initial analysis is carried out in the distribution of questionnaires, tests, and interviews to students and teachers. This analysis aims to determine the progress of modules, learning media, textbooks, and student metacognition. b) Student analysis is carried out analysis related to student characteristics to student knowledge and skills related to algebra material. c) Concept and task analysis, concept analysis is carried out to find out the concepts that students understand in learning algebra material while task analysis is carried out to analyze the main tasks that must be mastered by students to achieve minimum competence. e) The analysis of learning objectives is prepared to improve students' metacognition based on knowledge indicators and metacognition settings.

Second, the design stage is a continuation of the define stage. After the *define stage* is carried out, the next module prototype is designed and the prototype is then validated to media experts, material experts, and language experts. The final result of *this design stage* is in the form of the initial design of the module to be developed and the assessment instrument that will be used. The result of the initial design of the module developed is to compile the content of the module that refers to the specified product specifications and compile the module format. The module components are designed as follows: (1) writing rules, a) format in accordance with Iso: A4 (21 x 29.7 cm), b) sentence structure using the rules of the General Guidelines for Indonesian Spelling (PUEBI) and Subject Predicate Object of Information (SPOK), c) thickness of 56 pages, d) font size: 12, d) font type: Times New Roman, Calibri Light (Headings) and Berlin Sans FB Demi. (2) module framework, consisting of cover page, introduction, table of contents, introduction (module description, module usage instructions, competency mapping, and concept map), learning (subchapter 1 algebraic form operations and subchapter 2 algebraic form calculation operations), competency test, bibliography, glossary, answer key, and author profile. Some of the design for the development of the mathematics module in this study include:

1. the beginning of the module, the initial part of the module consists of: 1) the cover page, containing the competency fields, illustrations, and curriculum; 2) Introduction, containing information about the role of modules in the learning process; and 3) table of contents, containing the module outline and equipped with page numbers. The initial part of the module is shown in Figure 1.

Figure 1. Book Cover, Foreword, and Table of Contents

2. The core part, the part consists of introduction, learning, and competency test. The introduction contains a description of the module, instructions for using the module, competency mapping, and a concept map. Learning contains learning activities that refer to RME syntax. Learning is divided into 2 subchapters and each subchapter has a learning evaluation. The competency test contains multiple-choice test questions and descriptions. For more clarity the core part of the module is shown in Figure 2.

Figure 2. Book Cover, Foreword, and Table of Contents

3. The final section, the final section contains a bibliography, glossary, answer key, and author profile. For more clarity the core part of the module is shown in Figure 3.

Figure 3. Bibliography, Glossary, Answer Key, and Author Profile

Third, the development stage *in* this study develops RME-based modules through limited-scale trials. The limited scale trial in this study includes testing the practicality and effectiveness of the module. The instruments used are a practicality questionnaire as well as a test of knowledge and metacognition settings. The data generated in this activity is a questionnaire of teacher and student responses and test results. The data analysis technique used in the practicality test is the Benchmark Reference Assessment (PAP), while the data analysis technique in the effectiveness test is a multivariate t-test. Then a product efficacy test was carried out to find out which one produced better student metacognition scores between learning using RME-based mathematics modules (experimental class) or learning using mathematics textbooks (control class). The data analysis technique used at the product efficacy testing stage is the *multivariate mean difference* t-test.

The instruments in the practicality test used a response questionnaire that had been validated with expert validators before being given to teachers and students. The assessment of the module by students uses a student response questionnaire consisting of 15 items of statements developed from 3 aspects, namely interest, material, and language. The average score of the module assessment by students was 3.13 from 1 class with a total of 31 students. Based on the assessment category, the average score is in the range of $2.50 \leq \bar{X} < 3.25$ with the category of agreeing or practical if the RME-based mathematics module is used in learning. The assessment of the module by the teacher uses a teacher response questionnaire consisting of 12 statements. The results of the module assessment score by the teacher reached 86 with an average of 3.44. Based on the assessment category, the average score of the teacher's response questionnaire is in the range of 3.25 ≤ ≤ 4.00 with the category of strongly agreeing if the RME-based mathematics module is used in learning. Based on the results of the practicality test on the responses of students and teachers, it can be concluded that the RME-based mathematics module is declared practical to be used by students and teachers in learning. $\bar{X}$

The effectiveness test was carried out by comparing the experimental class and the control class. Data collection in the module effectiveness test was carried out by providing metacognitive knowledge questionnaires and metacognitive setting test questions both before and after learning using RME-based mathematics modules. This effectiveness test was carried out using a t-test of a multivariate paired sample with the results of the Fobs = 9.660 calculation with F0.05; 2.29 = 3.33. Based on the benchmark of the critical area DK = {F|F > F0.05; 2.29} so that Fobs ∈ DK, then the H0 test decision was rejected. It can be concluded that there is a difference in the average metacognition score between before and after learning using RME-based mathematics modules. Furthermore, a t-test of univariate paired samples was carried out on each component of metacognition. The results of the t-test calculation of univariate paired samples on metacognitive knowledge were obtained tobs = 2.380 with t0.05; 30 = 1,697. Based on the benchmark of critical areas DK = {t|t > t0.05; 30} so that the DK tobs ∈ , then the H0 test decision was rejected. It can be concluded that the average result of metacognitive knowledge score after using the RME-based mathematics module is better than the average result of the metacognitive knowledge score before using the RME-based mathematics module. The results of the t-test calculation of univariate paired samples in metacognitive settings were obtained tobs = with 7,381 t0.05; 30 = 1,697. Based on the benchmark of critical areas DK = {t|t > t0.05; 30} so that the tobs ∈ DK, then the H0 test decision was rejected. It can be concluded that the average score of metacognitive regulation after using the RME-based mathematics module is better than the average result of the metacognitive regulation score before using the RME-based mathematics module. Based on the results of the analysis, it can be concluded that the RME-based mathematics module is effectively used in learning. Effective means that it can improve metacognition, both knowledge components and metacognitive settings.

The data used for the product efficacy test came from the provision of metacognitive knowledge questionnaires and metacognitive regulation test questions after the completion of learning. The following is a summary of the data used in the calculation of the product efficacy test shown in Table 1.

Table 1.
Summary of Data Used in Product Efficacy Testing

	Experiment		Control	
	MK	MR	MK	MR
N	31	31	32	32
Highest Scores	52	20	51	20
Lowest Rate	36	1	34	3
Average	44,161	15,645	40,875	10,906

Information:
MK : Metacognitive Knowledge
MR : Metacognitive Regulation
N : Number of Students

Before conducting a product efficacy test, it is necessary to carry out a normality test and a homogeneity test of the variance and covariance matrix. The following is an elaboration of the normality test, the homogeneity test of the variance and covariance matrix, and the product efficacy test.

The results of the calculation of the normality test in the experimental class and control class in detail can be seen from the summary of the normality test results of each group. The following is a summary of the normality test results of each group shown in Table 2.

Table 2.
Summary of Normality Test Results in Balance Test

Group	Number of Students	Number $d_j^2 >$ χ20.05:2	Number $d_j^2 \leq$ χ20.05:2	Conclusion
Eksperimen	31	4	27	Normally distributed
Control	32	1	31	Normally distributed

Based on Table 2, it was obtained that the number of $d_j^2 \leq$ χ20.05:2 in the experimental group was 27 data or 87.10%, while in the control class group there were

31 data or 96.88%. Therefore, the H0 test result was accepted. It can be concluded that the initial ability related to metacognitive knowledge and metacognitive regulation in the experimental class and the control class is normally distributed multivariate.

Based on the calculation of the homogeneity test, $\chi 2obs$ = 5.685 with $\chi 2_{(0.05.3)}$ = 7.815. Based on the benchmark of the critical area DK = $\{\chi 2 \mid \chi 2 > \chi 2_{(0,05,3)}\}$, then $\chi 2obs \notin$ DK so that the test result H0 is accepted, which means that the variance matrix and covariance of the experimental class and the control class are the same (homogeneous).

The hypothesis in this study is that the average metacognition score of the experimental class is not the same as the metacognition score of the control class. The efficacy test of this product was carried out using *a multivariate mean difference t-test with the results of the Fobs* calculation = with 7,785F0.05; 2.60 = 3.15. Based on the benchmark of the critical area DK = {F|F > F0.05; 2.60} so that *Fobs* ∈ DK, then the H0 test result was rejected. It can be concluded that the average metacognition score of students in the experimental class (students in learning using RME-based mathematics modules) is not the same as the metacognition score of students in the control class (students in learning using mathematics textbooks provided by the school). Furthermore, a univariate mean *difference t-test* was carried out on each component (variable). The results of the calculation of the *univariate mean difference t-test on metacognitive knowledge were obtained t*obs = 1.940 with t0.05; 61= 1,670. Based on the benchmark of critical areas DK = {t |t > t0.05; 61} so that the tobs ∈ DK, then the H0 test decision was rejected. This means that the average metacognitive knowledge produced by the experimental class students is better than the metacognitive knowledge produced by the control class students. The results of the calculation of the *univariate mean difference t-test in the metacognitive setting were* obtained tobs = 10.896 with t0.05; 61= 1,670. Based on the benchmark of critical areas DK = {t |t > t0.05; 61} so that the tobs ∈ DK, then the H0 test decision was rejected. This means that the average metacognitive arrangement produced by the experimental class students is better than the metacognitive arrangement produced by the control class students. Based on the results of the analysis, it can be concluded that the metacognition of the experimental class students is better than that of the control class students. This means that students who use RME-based mathematics modules in their learning have better metacognition than students who use mathematics textbooks provided by the school in their learning.

Fourth, the dissemination stage (*Disseminate)* is carried out after the development stage is carried out. Furthermore, it was carried out by disseminating RME-based mathematics modules to grade VII students at the school where the research was conducted.

The results of this development research show that the RME-based mathematics module on the developed algebra material is declared valid. This is in accordance with the results of research conducted by Adrianti (2020), namely the module developed was declared valid based on the results of validation by learning material experts and educational technology experts. This module is designed to assist students in planning, monitoring and evaluating their learning process, as well as in solving math problems more effectively. The validity of this module is tested through a variety of methods, including validation by material experts, education experts, and field trials with students. The results of the study show that the mathematics module developed is declared valid and can improve students' metacognition ability (Rahmawati et al., 2021). Meanwhile, according to Setiawan and Handayani (2020) in their research, it was revealed that the use of well-structured modules based on metacognition theory can help students to become more aware of their own learning strategies. This allows students to develop critical and reflective thinking skills, which in turn can improve their learning outcomes in mathematics. The implementation of this module also shows an increase in student learning motivation, which is an important factor in academic success (Kusuma et al., 2019). Declared practical, field trials show that this module is practically used in various learning settings, both in traditional classrooms and in distance learning (Rahmawati et al., 2021). Assessment of the practicality of the module is carried out through direct observation, interviews with teachers and students, and analysis of student worksheets. The results of the study show that this module is easy to implement by teachers and can help students understand mathematical concepts more deeply. Teachers reported that this module helped them in teaching metacognition strategies, while students felt helped by the clear steps and guidance in the module (Setiawan & Handayani, 2020). In addition, this module also demonstrates flexibility in its use, allowing for customization according to the needs and abilities of students (Kusuma et al., 2019). Declared effective, the results of the study are in accordance with research conducted by Rahmawati et al. (2021) showing that the use of this module significantly improves students' metacognition skills. Students who use this module show an improvement in their critical and reflective thinking skills, which in turn improves their performance in maths subjects. Evaluation of the effectiveness of the module is carried out through *pre-test* and *post-test* tests, as well as qualitative analysis of student worksheets and interviews with teachers. The results showed a significant improvement in students' metacognition scores after using the module (Setiawan & Handayani, 2020). In addition, teachers reported that this module helped students become more aware of their own learning strategies and more confident in solving math problems (Kusuma et al., 2019). Declared effective, this result agrees with the results of research conducted by Adrianti (2020), students who learn using RME have better metacognition scores than students who use mathematics textbooks. Analysis of *pre-test* and *post-test* data showed a significant improvement in students' metacognition abilities in the experimental group compared to the control group (Setiawan & Handayani, 2020). In addition, interviews and observations showed that students who used this module were more active in the learning process and more confident in solving math problems (Kusuma et al., 2019). The results of another study conducted by Rahmawati et al. (2021) show that this module is able to significantly improve students' metacognition skills. Students who use this module show improvement in their ability to plan learning strategies, monitor their own understanding, and evaluate their learning progress in solving math problems. The effectiveness of the module was tested through a quasi-experimental research design with control groups and experiments.

IV. Conclusion

The results of this study can be used as one of the bases in determining teaching materials in teaching and learning activities so that they can improve students' metacognition. And this research makes a new contribution in the field of mathematics education and is expected to be useful for teachers and curriculum developers in developing mathematics learning modules that are more effective and meaningful for students.

The results of this research in the form of a printed module are expected to be an inspiration for other researchers to make this module in the form of an interactive mathematics module so that other researchers do not need to print modules to be shared with students. This study was not accompanied by interviews with students during data collection to find out students' metacognition. If other researchers want to develop similar research, it is hoped that there will be an interview process to find out the metacognition of individual students.

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