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The Effectiveness of Realistic Mathematics Education on Learning Outcomes and Critical Thinking for Elementary School Students

[1]Aida Nur Widiana, [1]Mukti Sintawati*, [2]Ginanjar Abdurrahman
Corresponding Author: * mukti.sintawati@pgsd.uad.ac.id
[1] Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[2] Universitas Muhammadiyah Jember, Indonesia

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ABSTRACT

Implementing learning on mathematics material that does not provide facilities for students to explore critical thinking skills results in a lack of student learning outcomes. The teacher-centred learning process makes many students passive when learning takes place, and low student learning outcomes and critical thinking are also caused by the use of less varied learning models. This makes researchers apply an approach with PMRI (*Pendidikan Matematika Realistik Indonesia* or Indonesian Realistic Mathematics Education). This study aimed to determine the effectiveness of PMRI in improving fourth-grade students' learning outcomes and critical thinking. This research was a pre-experimental study; the subjects in this study were fourth-grade students with 20 students. The design in this study is quasi-experimental with the form of one group pretest-posttest design. Data collection was carried out using test, observation and documentation techniques. Data analysis techniques were carried out by Normality Test, Homogeneity Test, and Paired t-test. The results showed that PMRI learning can improve students' learning outcomes and critical thinking. This is evidenced by the average value of learning outcomes pretest (69.65) and post-test (87.35). Then the average value of critical thinking at the first meeting (68.05) and the second meeting (78.85). The conclusion that can be drawn is that students' learning outcomes and critical thinking have increased after PMRI was applied to fourth-grade students.

Keywords
Critical Thinking
Elementary School
Learning Outcomes
Realistic Mathematics

Introduction

Learning is a process of student interaction with educators and learning resources in a learning environment. Learning is assistance provided by educators/teachers so that acquiring knowledge and knowledge can occur, mastering skills and character, and forming attitudes and beliefs in students. In other words, learning is a process to help students learn well. Learning, in other words, is a person's activity related to obtaining a change.

Mathematics taught at all levels of education is one of the lessons; mathematics is the subject matter that every student must take. In the 2013 Curriculum, mathematics has a vast scope of material to develop abilities for elementary school students. Mathematics subjects aim to make students able to think logically, critically, and creatively analyse, develop the ability to work together among students and train psychologically and spiritually. Mathematics needs to be learned because mathematics, in general, is an integral part of general education; mathematics is studied to understand the world and becomes a tool and language for solving problems [1].

Contribution to mathematics in elementary school can help students solve problems in everyday life and help students think logically. Learning mathematics in elementary schools is limited to mastering procedures and facts and understanding math skills' concepts. One of the math skills is critical thinking. Critical thinking is needed to improve language and analytical skills and can train students to get used to thinking; by thinking critically, students are expected to be able to use the potential of their minds to solve various problems that exist in everyday life, besides that students are also able to get maximum learning results. This is in line with the mathematics curriculum in schools, which is expected to teach students to reason and analyse a situation according to the context of everyday life [2].

Critical thinking skills are crucial; Indonesian students have not appropriately mastered these abilities. This can be seen from the TIMSS (Trends in International Mathematics and Science Study) results 2011 regarding cognitive processes. The average correct answer on the reasoning abilities of Indonesian students is only 17% or 13% lower than the intermediate international students. In addition, students' global reasoning abilities are also lower than knowledge and applications.

There is a fact that the 2011 TIMSS results in the domain of cognitive processes show that students' weak reasoning abilities are an indication of soft critical thinking skills. Ref. [3] states that reasoning includes essential, critical, and creative thinking. Therefore, the 2011 TIMSS results can be used as a basis that students' necessary thinking skills require special attention.

Students' critical thinking skills cannot develop if learning is still centred on the teacher. The teacher is more dominant in conveying material in the classroom so that students can only listen and tend to be passive with the material presented, the mathematics learning delivered is also still oriented towards existing mathematics, so it is less helpful in solving problems or even making other problems, making mathematics considered difficult and scary. Ref. [4] revealed that students feel anti and afraid of learning mathematics before they study it, so it is embedded in students that mathematics is complex.

This makes students busy in class, playing with desk mates, and even sleeping while learning occurs. If this continues, learning in the classroom will run poorly. If this continues, it will affect learning outcomes. Learning outcomes are obtained after carrying out learning activities. Learning outcomes are the level of success obtained after studying a subject matter; learning outcomes are usually expressed in numbers or letters. Learning outcomes are obtained from the teacher's assessment; from the results of the teacher's review, it can be measured how far students understand the material.

According to Ref. [5], low student mathematics learning outcomes are caused by many things, such as; dense curriculum, ineffective learning media, inappropriate learning strategies and methods chosen by teachers, poor evaluation system, lack of teacher ability to arouse student motivation, or also because the learning approach is still conventional. Hence, students are only a little involved in the learning process.

This is in line with the results of a survey conducted by the Program for International Student Assessment (PISA) for Indonesia in 2018 regarding mathematics ability announced by The Organization for Economic Co-operation and Development (OECD). PISA measurement aims to evaluate the education system by measuring student performance, especially in three main areas, namely mathematics, science, and literacy. From the 2018 PISA score, Indonesia is ranked 74 out of 79 countries below Thailand and Uruguay, where Indonesia's math score is 379 while the average for all OECD countries is 489; as in previous years, Indonesia's ranking could have been better. Other data showing the low mathematics achievement of Indonesian students can be seen from the results of the 2016 National Center for Education in Statistics survey of 41 countries in learning mathematics, where Indonesia was ranked 39th. This shows that the quality of education in Mathematics in Indonesia is relatively low.

Learning outcomes are something that only stands with others. Learning outcomes are an accumulation of various factors that affect students; these influences can come from within the students themselves (internal factors) and outside (external factors). Factors from within students include intelligence, critical thinking skills, motivation, health, ways of learning and independent learning. At the same time, external factors include the family environment, school environment, and community environment.

This problem arises not only because of the need for students' abilities but also because of the unsupportive learning environment. For example, from the results of interviews conducted with the teacher, learning still uses lecture and assignment models, needs to be more student-centred and more varied, and use effective models to support lessons. Students who do not understand the material feel afraid to ask questions because the teacher does not give them time to ask questions because students think that mathematics is a complex and scary subject.

The success of a lesson in elementary school is, of course, influenced by several things, such as models, methods, the teacher's teaching style, and the approach taken by the teacher. The teacher must start changing and improving the way he teaches; mathematics cannot be guided only by lectures, discussions and questions and answers, but implementation is still limited to using guidebooks. It makes students need a broader understanding, even though learning mathematics needs realistic concrete evidence [6]-[8]. Therefore an appropriate approach is required; one learning approach teachers can use is the PMRI.

PMRI is a student-oriented learning approach, stating that mathematics has a real relationship with human activities in everyday life; education must be realistic or accurate, especially for elementary students. Therefore PMRI is an approach that can introduce students to the real world as teaching material. Ref. [9] argues that the main principle of PMRI is that students must actively participate in the learning process. Students are allowed to build their knowledge and understanding; with this, students will remember the material presented more because they are directly involved in learning; it will also impact students' ability to think critically, and learning outcomes will increase. It can be said that learning PMRI is practical to do.

This research will focus on teachers' learning approach in the teaching and learning process at school. The learning approach will later impact fourth-grade students' critical thinking and learning outcomes. Researchers will research critical thinking and student learning outcomes with a student-oriented system, namely PMRI. This approach relates lessons to everyday life. Researchers study these basics in implementing PMRI to improve learning outcomes and critical thinking.

Based on the descriptions above, the formulation of the problem from this research is: (1) Is the implementation of PMRI effective in increasing learning outcomes? (2) Is the implementation of PMRI effective in increasing critical thinking? By formulating the problem, this study aims to describe:

1. To determine the effectiveness of Indonesian Realistic Mathematics Education (PMRI) in improving the learning outcomes of fourth-grade students.
2. To determine the effectiveness of PMRI in improving critical thinking skills for fourth-grade students.

In theory, the benefits of this research can contribute in the form of studies on the effectiveness of PMRI in learning outcomes and critical thinking skills. At the same time, it can be used practically as a reference in designing more varied and enjoyable learning.

Methods

This research is a Quantitative Pre-experimental model with a Quasi-experimental Design in the form of one group Pretest-posttest design. This study only consisted of one group, namely the experimental group; before being given treatment, the experimental group was assigned an initial test (pre-test), the next stage was given treatment, and a final examination (post-test).

The research process was carried out four times. The first meeting was giving the Pretest, the second and third meetings were learning with PMRI then, at the last meeting, namely sharing the Posttest, each session was 1 lesson hour. In this study, researchers collaborated with class teachers. This research was conducted by the characteristics of PMRI learning adopted from research from Ref. [10], which include: using a model, interactive, using context, using student contributions, and linkages between topics. The steps in learning with PMRI include Preparation, Opening, Learning Process and Closing.

This research was conducted at a particular public elementary school located in Bowongso, Indonesia, from April to May 2022, even semester; the population of this study was all four grade students, totalling 20 students. The population is the entire object in an area that meets specific requirements related to research problems or the whole unit or individual within the study scope. The sample in this study was taken using Saturated Sampling, where all population members were used as samples.

The data collection method used in this study is the method of testing, observation and documentation. The test used in this study was objective in the usual multiple-choice form with 15 questions. The preparation of these questions refers to essential competencies (or *Kompetensi Dasar*/ KD) and indicators. The KD used includes: 1) Analyzing the properties of regular and irregular polygons, 2) Explaining and determining the perimeter and area of squares, rectangles and triangles. Observations were made by observing the learning activities;

the assessment consisted of observation sheets and evaluation questions. The documentation in this study is lesson plans, lists of student names, lists of student groups, lists of student group values, lists of individual values, and photos of learning activities.

The data's validity and reliability are done to determine whether an instrument is valid and reliable. Validity is a measure that shows an instrument's validity or validity levels. An instrument is good if it can measure what is desired [11]. Testing the validation of the research instrument can show how much the instrument can measure the variables contained in a study. Reliability is expressed by a coefficient ranging from 0 to 1.00. The higher the reliability coefficient close to 1.00, the lower the reliability [12].

Data normality tests, hypothesis testing and paired sample T-tests were used to analyse data. The normality test aims to determine the condition of the data, whether the data is normally distributed or not. This study used the Kolmogorov-Smirov test and the Shapiro-Wilk test. The test used is the Shapiro-Wilk test because of only 20 respondents. The significance level used is 5% with the following value rules:

- Significance value (sig) < 0.05, the population is not normally distributed;
- Significance value (sig) > 0.05, the population is normally distributed

Once proven normal, then a homogeneity test is carried out, a homogeneity test is carried out to test whether the two samples taken have a homogeneous variant or not.

The rate used is 5%. The significance value criteria used are as follows:

- Significance value (sig) < 0.05, the population has an inhomogeneous variance.
- Significance value (sig) > 0.05, the population has a homogeneous variance.

The Paired Sample T-Test was done by observing the significance value of t at the α level used (this study uses an α level of 5%). The analysis is based on a comparison between the significance value of t and a significance value of 0.05, where the conditions are as follows:

- If the significance of t <0.05, then H0 is rejected, which means that the independent variable has a comparative difference to the dependent variable.
- If the significance of t > 0.05, then H0 is accepted, namely that the independent variable has no comparative difference to the dependent variable.

Results

A. Learning outcomes

Learning outcomes are learning outcomes that are an integral part of the learning process. Learning outcomes are obtained after carrying out learning activities, meaning that the final product or ultimate goal of learning is to get learning outcomes. Learning is a familiar word in human life. Ref. [13] states that learning is an activity carried out to produce changes, both

changes in behaviour itself, which will be permanent. The results of the initial test (pretest) are the ability of students' learning outcomes on the material of regular and irregular polygonal shapes, perimeter and area of flat bodies, where students have yet to be given treatment with the PMRI approach.

The results of an initial test, also known as a pretest, were taken by 20 students—the total number of students who took the pretest, which is 20. The mean pretest score is 69.65, which indicates that the average score of the 20 students is slightly below 70 marks. The median pretest score is 70.00, which shows that half of the students scored above 70 spots, and half scored below 70 marks. The standard deviation of the pretest scores is 10.091, which indicates that the scores are somewhat spread out but not excessively so. The pretest results show that the average score of the 20 students is slightly below 70 marks, with half scoring above and half scoring below 70. The most common score is 67, which is somewhat spread out, but not excessively so, with a standard deviation of 10.091.

The results of a treatment given to a group of 20 students as evidenced by their post-treatment test scores. The students' mean, or average, score after receiving the treatment is 87.35, indicating the average score is relatively high. The median score is 87, meaning half of the students scored above 87 and half below 87. The mode score is also 87, indicating that this was the most frequently occurring score among the students. The standard deviation of the scores is 7.095, which suggests that the scores are not widely spread out, and most of the students' scores are relatively close to the mean.

It means that the treatment positively affected the student's performance. The average score of 87.35 is higher than the pre-treatment average of 69.65. The median and mode of 87 indicate that most students scored close to this score. The low standard deviation of 7.095 indicates that the student's scores were clustered around the mean score and not significantly varied. This suggests that the treatment effectively produced consistent improvements in student performance (see Fig. 1 for the result of pre-test and post-test).

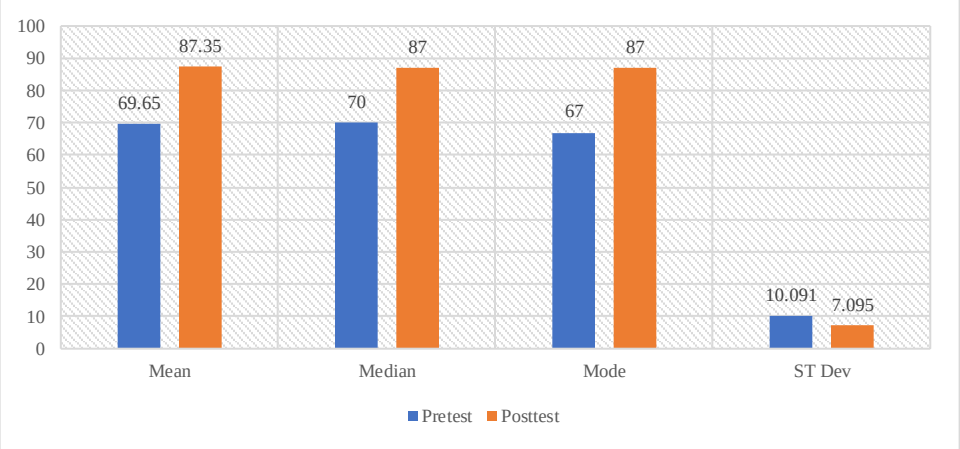


Fig. 1. The learning outcome result of the pre-test and post-test

The prerequisite test is carried out before testing the hypothesis using the t-test. The prerequisite test includes the normality test and homogeneity test. Based on the n normality test results, it was obtained that the Normality Test for mathematics learning outcomes had a normal distribution of sig values for pretest data of 0.132 > 0.05 and posttest of 0.138 > 0.05. While the results of the homogeneity test for mathematics learning outcomes Levene arithmetic test is 3.330 with a sig value of 0.076 because sig > 0.05, the psychomotor value data is stated to have the same homogeneous variant value.

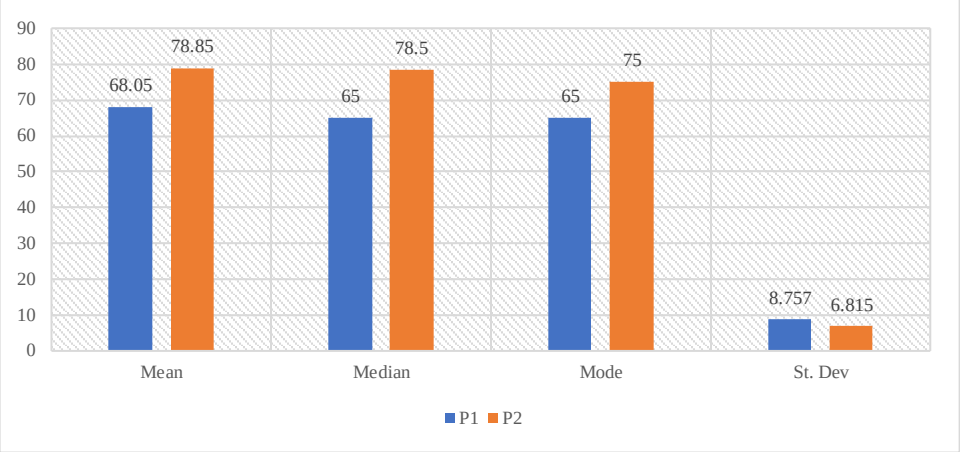
In the paired sample t-test, there is a requirement that if the significance of t <0.05, then H0 is rejected, which means that the independent variable has a comparative difference from the dependent variable. If the significance of t> 0.05, then H0 is accepted; namely, the independent variable has no relative difference from the dependent variable. The results of the t-test of learning outcomes obtained t-table= 1.724. while t-counted= -10.355 and is in the area of rejection of Ho or the area of acceptance of Ha. While the probability value or Sig. 2 tailed is 0.000 <0.05, Ho is rejected. From testing the t-test at a confidence level of 0.95 or an error level of 0.05, it can be concluded that there is a difference in the average score of learning outcomes before and after learning using PMRI.

B. Critical thinking

Thinking is an activity of reasoning and processing information critically to solve problems. According to Ref. [14]-[16], critical thinking is essential for education because it includes evaluating, internalising and acting beyond knowledge and values. Ref. [17] argues that "critical thinking is done reflectively and productively and evaluates existing evidence". Furthermore, Ref. [18] defines critical thinking as "skilful and active interpretation and evaluation of observation and communication, information and argumentation". In addition, Ref. [29] suggests that critical thinking is the ability to think logically, reflectively and productively, which is applied in assessing situations to make sound judgments and decisions. Based on the definition of critical thinking by the experts above, it can be concluded as follows that critical thinking is an activity of reasoning thinking which is a directed and transparent process using an idea or idea that goes through a process of analysis, explanation and development of an argument or opinion that In the end a conclusion will be taken from the ideas that have been achieved and have been developed before. See Fig. 2 for the critical thinking before and after the learning activities.

The critical thinking normality test also has a normal distribution of sig values for the initial critical thinking observation score of 0.124 > 0.05 and the final meeting score of 0.167> 0.05. These results indicate that the critical thinking scores at the first and second meetings are

normally distributed. The homogeneity test shows that the Levene test statistic is 0.814 with a sig value of 0.373 because sig > 0.05, the psychomotor value data is declared to have the same homogeneous variant value.



Remark: P1 (before), P2 (after)

Fig. 2. The critical thinking score before and after learning

Critical thinking t-test results obtained t-table= 1.724. while t-counted= -7.414 and is in the area of rejection of Ho or the area of acceptance of Ha. While the probability value or Sig. 2 tailed equal to 0.000 <0.05, then Ho is rejected. From testing the t-test at a confidence level of 0.95 or an error level of 0.05, it can be concluded that there is a difference in the average score of critical thinking before and after learning using PMRI.

Discussion

Based on the research, there is a difference in the increase in student learning outcomes between the pretest and posttest due to the treatment given, namely PMRI. This happens because PMRI clearly understands the relationship between mathematics and everyday life. This aligns with the characteristics of learning mathematics in elementary school, according to Ref. [20] Amir (2014: 78-79) states that it is essential to teach mathematics using the spiral method, which is always associated with previous material, from concrete to abstract things or simple concepts to more difficult ones, from specific to general events, and learning should be meaningful. This is also in line with research conducted by Ref. [21] that there is a significant influence between learning mathematics and PMRI.

PMRI learning also provides a clear and operational understanding to students. During the learning process, students look active when participating in learning, learning becomes more fun, students learn to solve problems in pictures or schemes, and students think about various possible answers through the group discussion process or ask the teacher.

This is in line with the characteristics of PMRI. According to Ref. [22], PMRI has five characteristics; the first is using a model; the model used can be actual objects, pictures and

schemes that can be used to support learning. Secondly, interaction between teachers and students, students with students, and Interaction can be in the form of discussion and explanation. The third is using context; context is the natural environment of students both culturally and geographically; contextual problems do not have to be problems in the real world but can also be in other forms, such as using teaching aids or games. The fourth uses student contributions, contributions that students can make when learning, namely ideas or ideas, and opinions with diverse answers. Students have the freedom to develop a variety of strategies. The five interrelationships between topics that mathematics has interrelated concepts are not known separately. This means that learning mathematics with PMRI provides many opportunities for students to carry out learning activities optimally to influence the competence of mathematical knowledge.

The PMRI approach has the advantage of being oriented towards realistic student reasoning by the demands of a competency-based curriculum. This is shown in developing a practical, logical, critical and honest mindset. In addition, PMRI also provides opportunities for students to work together to solve a problem in learning, become more responsible for their respective tasks, and get the chance to exchange ideas with their friends. This is consistent with the characteristics of PMRI from Ref. [23], which confirms that the characteristics of the PMRI approach are: students are more active in thinking, context and teaching materials are directly related to the school environment and students, and the role of teachers are more involved in designing teaching materials.

PMRI is an approach that refers to constructivist learning. Constructivism is the knowledge that students gain from constructing their thoughts related to everyday activities that students can imagine. In this case, education will be more meaningful so that students can rediscover mathematical concepts naturally and be free to express opinions and develop reasoning power. This research aligns with research conducted by Ref. [24], which shows that the PMRI approach influences students' mathematics learning outcomes before and after implementing PMRI. This research is also in line with a study conducted by Ref. [25], showing that the PMRI approach can be applied in schools to improve the critical thinking skills of elementary school students.

In addition, PMRI has advantages. According to Ref. [26], the benefits of PMRI are: provides clear and operational understanding to students about the relationship between mathematics and everyday life (real world life) and about the use of mathematics in general for humans; provides a clear and operational understanding to students that mathematics is a field of study that is constructed and developed by students themselves, not only by those who are called experts in that field; provides a clear and operational understanding to students that

the method of solving a problem or problem does not have to be single, and does not have to be the same from one person to another, and provides a clear and operational understanding to students that in learning mathematics, the learning process is the main thing, and to learn mathematics, one must go through that process and try to find mathematical concepts for themselves with the help of other parties who know better (e.g. Teacher).

This research implies that PMRI is a learning alternative teachers can use to be applied in fourth grade, especially in the learning process, to optimise students' mathematical knowledge competencies. PMRI provides opportunities for students to be active and motivated when expressing their ideas, and students can understand the material because students in learning are allowed to solve problems that are often found in real life so with PMRI, the results of learning mathematics and critical thinking increase.

This research's success is inseparable from the teacher's active role as an educator and students as targets in education. Using a learning model to convey material gives students more ability to address problems during the learning process. Students become more courageous in expressing opinions, analysing a problem that occurs, and being able to conclude an activity that has been carried out. This, of course, affects the learning outcomes and students' critical thinking; the more students can analyse a problem, the better students critical thinking skills. So it can be concluded that PMRI can improve students' learning outcomes and critical thinking.

Conclusion

Based on the data analysis and discussion of this quantitative research, it can be concluded that the learning process with PMRI effectively improves students' learning outcomes and critical thinking. Furthermore, the researchers would like to provide the following suggestions: for teachers to apply this PMRI approach on an ongoing basis so that students' learning outcomes and critical thinking skills in learning mathematics continue to increase.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Authors

Aida Nur Widiana is an elementary school teacher education student at Universitas Ahmad Dahlan. She has always been active in student activities, especially those related to school and community development. She has been actively involved in various student organisations and volunteer programs. She is known for her dedication and hard work organising events and activities to empower communities and promote education. As a student of Elementary School Teacher Education, she is preparing herself to become a dedicated and compassionate educator who will positively impact the lives of her students. (email: aida1800005172@webmail.uad.ac.id).

Mukti Sintawati is a lecturer at Universitas Ahmad Dahlan. She was born and raised in Yogyakarta, Indonesia. After completing her undergraduate studies at Yogyakarta State University in 2011, she continued her education and obtained her Master's degree from the same university in 2015. She has a background in Elementary School Teacher Education. She is also actively involved in various elementary education research and curriculum development activities. She always strives to remain active and involved in social activities in her community. (email: mukti.sintawati@pgsd.uad.ac.id).

Ginanjar Abdurrahman is a lecturer at Universitas Muhammadiyah Jember. He was born and raised in Kebumen, Indonesia. After completing his undergraduate studies at Yogyakarta State University in 2011, he continued her education and obtained her Master's degree from the same university in 2015. He has a background in Mathematics Education. He is also actively involved in various elementary education research and curriculum development activities. He always strives to remain active and involved in social activities in his community. (email: abdurrahmanginanjar@unmuhjember.ac.id).