The effect of RME-based e-module on students' creative thinking in mathematics

Eka Dewi[1,*]

[1]Sempoa SIP Training Center, Lampung, Indonesia
*Correspondence: ekadewi0012@gmail.com

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Abstract

This study aims to investigate the effect of RME-based e-module on students' creative thinking in mathematics. For this purpose, this study employed quasi experimental research, in particular non-equivalent control-group with pretest and posttest design. A total of 52 students from an experimental and a control group were involved in this study. The data was collected by using a test instrument measuring creative thinking which covered four aspects, i.e. fluency, flexibility, originality, and elaboration. The data was analyzed by using descriptive and inferential statistics. The descriptive statistics shows that students' scores on creative thinking test increased from pretest to posttest in both experimental and control groups. Regarding the levels of students' creative thinking, improvement was also observed in both groups. In the pretest all students in the two groups were in low category, but after the intervention these numbers decreased to 11% for the experimental group and 53% in the control group. An inferential statistics was employed to investigate the effect of RME-based e-module on students' creative thinking. It is found that students who learned by using RME-based e-module performed significantly better than their counterparts in the control group.

Keywords: creative thinking, e-module, Realistic Mathematics Education

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INTRODUCTION

The Industrial Revolution 4.0 has a great influence on various sectors, both economic, political, social and also education system (Noh & Karim, 2021). The World Economic Forum states that 65% of students will work in jobs that currently have not yet existed and 47% of current jobs will be replaced by technologies in the next decade. Consequently, this is a big challenge for education system in preparing human resources to meet the demands of the future world of work (Elayyan, 2021). The World Economic Forum reports that there are 10 abilities required by the world of work in the future, namely complex problem solving, critical thinking, creativity, people management, emotional intelligence, coordinating with others, judgment and decision making, service orientation, negotiation, and cognitive flexibility. This shows that creativity is a very important ability for students to master in the Industrial Revolution 4.0 era.

Creative thinking corresponds to the abilities that include the aspects of fluency, flexibility, originality, and elaboration (develop, combine, and enrich) an idea (Romaito, Safitri, Nisah, Apriani, Afsari, & Dwichandra, 2020). Creative thinking plays an important role in generating many ideas to solve problems (Nasution, Yulia, Anggraini, Putri, & Sari, 2020). Creative thinking will grow well if students are facilitated to learn according to their wishes, are given the trust to think, and are facilitated to dare to convey their new ideas (Adiastuty, Waluya, & Aminah, 2020). According to Thohari, Budiyono, and Pratiwi (2020) creativity in general is a manifestation of creative thinking. Creative thinking is something that is needed to be able to solve a problem or find alternative solutions to a problem (Adiastuty et al., 2020). Creative thinking is a mental process that produces new and unique solutions to a given problem or to find new ideas and find various alternative solutions to a problem.

Creative thinking is one of the abilities that must be possessed by students because coping the demands of the 21st century requires human resources who possess critical thinking and problem-solving skills, communication and collaboration skills, and creativity and innovation (Trilling & Fadel, 2009). The 21st century learning requires students to have the ability to think creatively. As a result, there has been a change in the paradigm of the education curriculum in realizing 21st century skills for every subject in schools, including mathematics. Creative thinking is an ability that students need in learning, especially learning mathematics because it is a thinking exercise that revives intuition, imagination, amazing perspectives, and unexpected ideas. Creative thinking is also an important ability in mathematics because it is related to the ability to produce creative work, innovative ideas, or innovative products. In addition, mathematical creative thinking is also important to develop because it relates to the use of mathematical knowledge that has been learned to solve problems using new and unusual strategies (Pane, Syahputra, & Mulyono, 2014).

With respect to improving students' competence, Brewer and Stasz (1996) proposed three important aspects, i.e. curriculum content, instructional strategies, and instructional resources. Curriculum content corresponds to the coverage of subjects and topics that are learned by students. Regarding instructional strategies, the approaches used by teachers in the classroom can influence students' learning process. Lastly, instructional resources cover learning materials, media, and resources which are used in the classroom activities. Among various types of instructional resources, books or modules can be considered as an essential means for students' learning because they are mostly used by students. In line with the development of technology, e-module (electronic module) is a potential learning media for learning mathematics. The use of e-modules is also an effort to integrate technology in learning to produce technologically literate human resources (Ilmi, Arnawa, Yerizon, & Bakar, 2021 and Risma & Yulkifli, 2021). The use of technology in learning is also a means to develop interesting learning models and motivate students to learn independently. The use of E-module is also interesting because it can be displayed on a smartphone which is a technology that is currently very familiar and can be carried anywhere by students. Learning that utilizes smartphone technology really helps the learning process and meets the demands of technological literacy (Ilmi et al., 2021 and Risma & Yulkifli, 2021). Moreover, e-module is also found to be an effective medium to improve higher order thinking skills. The results of research by Yusuf et al. (2020) stated that the use of e-modules in learning can improve students' Higher Order Thinking Skills (HOTS). Research conducted by Sukestiyarno and Hartutik (2020) concluded that learning mathematics using the Seven Jump method assisted by the e-module effectively improves students' problem-solving skills in class X statistics. The results of Seruni, Munawaroh, Kurniadewi, and Nurjayadi's (2020) research stated that the professional flip PDF e-module shows that the use of e-module through problem-based learning is effective in increasing critical thinking skills. The results of research conducted by Haryanto and Rustana (2021) also stated that the use of guided inquiry-assisted e-modules can improve students' critical thinking skills.

The important components of e-module is not only its digital platform, because the content and learning approach of module also play crucial role to support students' learning. A content or approach that can be used to develop students' creative thinking is Realistic Mathematics Education (RME). A number of studies (e.g. Ndiung, Sariyasa, Jehadus, Apsari, 2020; Royhana, Widiatsih, Armaja, & Septory, 2021; Ismunandar, Gunadi, Taufan, Mulyana, & Runisah, 2020) have shown that the use of RME in the learning of mathematics can develop students' mathematical creativity. RME is a learning theory which is based on Freudenthal's view that "mathematics as a human activity" (Gravemeijer & Terwel, 2000). This means that mathematics is not given as a ready-made product, but as a mathematical activity. According to Gravemeijer and Terwel there are three principles of RME, namely *guided reinvention*, *didactical phenomenology*, and *self-developed models*. Guided reinvention corresponds to the use of didactic phenomena that will be explored by students through the process of mathematization. Didactical phenomenology is a principle related to the use of didactic phenomena which students will explore through the process of mathematization. Self-development models are principles related to making information models towards formal models by students. Furthermore, there are five key principles of RME, namely phenomenology exploration, bridging by vertical instruments, student contributions, interactivity, and intertwining. Phenomenology exploration relates to the existence of a phenomenon that students can explore towards horizontal mathematization, vertical mathematization, and progressive mathematization. This phenomenon is in the form of "realistic" contextual problems which are used as a starting point for building mathematics. Bridging by vertical instruments related to self-development models to bridge the levels of informal mathematics and formal mathematics. Student contributions are characteristics related to student contributions in horizontal, vertical and progressive mathematization, making situational models, models of, models for, and formal models, as well as student contributions in the process of rediscovering mathematical concepts. Interactivity is related to student interaction with the teacher according to the guidance principle, and interaction with other students during the mathematization process. Intertwining relates to students needing the opportunity to link the knowledge they have learned with new knowledge to gain a comprehensive understanding.

Considering the potential of e-module to develop students' higher order thinking skills and also the positive effect of RME on students' mathematical creativity, this study concerns the integration of e-module and RME as a learning medium. Therefore, this study aims to investigate the effect of RME-based e-module on students' creative thinking in mathematics.

METHODS

Research Approach

This study used quasi-experimental research approach. This approach was chosen because in this study the researchers did not form a special group (class) to be experimented with but used a group (class) that already existed at the school where the research was conducted. This study used two classes, namely the experimental class and the control class. The experimental class was given learning using an e-module based on a realistic mathematics approach and the control class was given learning using a realistic mathematics approach (without an e-module). The research design used in this study was non-equivalent control-group with pretest and posttest design. According to Johnson & Christensen (2012) this non-equivalent comparison design group forms an experimental and control group through a pretest and post-test.

Students in the experimental group learned mathematics by using RME-based e-module, whereas the students in the control group learned in a classroom that implemented RME only. The students in the experimental group did the phenomenological observation by watching videos, whereas their counterparts in the control group worked with paper-and-pencil activities only. Furthermore, online worksheets were also used in the experimental group so that students got feedback directly after they finished the worksheets. In this respect, the students in the control group had to wait for whole class discussion to confirm whether their works in the worksheet were correct.

Population and Sample

The population in this study were all class VIII students at MTs Muhammadiyah Sukarame for the 2021/2022 academic year, which consisted of three classes, namely classes A, B, and C. The sampling technique used in this study was a purposive sampling technique as it considered certain characteristics. In this study, two classes were selected as research samples based on the recommendation of the mathematics teacher at school. The two classes selected as samples were class VIII A and class VIII B because based on the teacher's statement that these two classes had the same mathematical ability characteristics. Meanwhile, class VIII A is the experimental class which uses e-module based on a realistic mathematics approach, while class VIII B is the control class which uses a realistic mathematics approach.

Research Instrument

This mathematical creative thinking ability test was used to collect data related to students' mathematical creative thinking abilities before and after being given treatment. The test conducted before the treatment (pre-test) aimed to determine the initial abilities in the control class and the experimental class. While the test after being given treatment (Posttest) aims to determine the achievement of competence in the control class and the experimental class. The test used in this research was a written test in the form of a description. This test was structured based on the indicators of mathematical creative thinking (see Table 1).

Table 1. The indicators of test instrument to measure students' creative thinking

Component	Description	Test Item
Fluency	The ability to generate more than one alternative answer to a math problem	1, 3
Flexibility	The ability to work on math problems with various ways of solving	2, 4
Novelty or originality	different problem-solving abilities or pure problem-solving ideas from new/unique personal thoughts	3, 5
Elaboration	Ability to explain in detail	1, 3

In order to obtain a reliable measurement, the test instruments were checked for its reliability before it is used for the tests. Coefficient Cronbach's alpha coefficient obtained from the output results were 0.712 and 0.740 for pretest and posttest respectively. It means the test instruments were reliable.

Data Analysis

Descriptive and inferential statistics were used to analyze the data. Descriptive analysis is used to describe the research data that has been obtained from the results of the pre-test and post-test in the experimental and control classes. The descriptive analysis that was carried out consisted of an analysis of the average, standard deviation, highest score, and lowest score for data on mathematical creative thinking before and after the classroom intervention. Descriptive analysis was also carried out to determine the average and percentage of achievement for each indicator of mathematical creative thinking ability.

The creative thinking test that was used in this study consisted of five essay questions with the highest score of 100 and the lowest score of 0. Data on mathematical creative thinking was categorized into several criteria to determine the achievement level of students' mathematical creative thinking abilities. The criteria for mathematical creative thinking ability used in this study are "very high", "high", "moderate", and "low" (see Table 2).

Table 2. Categories of students' creative thinking in mathematics

Score interval	Criteria
$90 < x \leq 100$	Very high
$80 < x \leq 90$	High
$70 < x \leq 80$	Moderate
$x < 70$	Low

Inferential statistics was also used to analyze data on students' mathematical creative thinking. This analysis was aimed to test the research hypothesis. Independent t-test was used to test compare the performances of students in the two groups.

RESULTS AND DISCUSSION

Students' creative thinking in mathematics

Data on Students' Mathematical Creative Thinking Ability were obtained from the results of the pretest and posttest Mathematical Creative Thinking Ability both in the experimental class which was given Learning Using E-Module Based on Realistic Mathematical Approach and in the control class which was given Learning with Realistic Mathematical Approach. In summary, data on Students' Mathematical Creative Thinking Ability obtained from the two classes can be seen in Table 3.

The increase in the ability to think creatively can be seen from the increase in the total average and the average for each indicator of the ability to think creatively mathematically, namely the indicators of fluency, flexibility, originality, and elaboration. Based on Table 3, it can be seen that the students' Mathematical Creative Thinking Ability in the experimental class which provides learning using the Realistic Mathematical Approach-based E-Module is better than the control class which is given learning using the Realistic Mathematical Approach. This can be seen from the final condition of the students' Mathematical Creative Thinking Ability both in terms of the total average and the average of each indicator showing that the final condition or after treatment of the class using the E-Module based on the Realistic Mathematical Approach is higher than the class using the Realistic Mathematical Approach.

Table 3. General overview of students' creative thinking in mathematics

No	Aspect	Experimental Group (RME-based e-module)		Control Group (RME with paper-and-pencil)	
		Pretest	Posttest	Pretest	Posttest
1	Fluency	0.64	62.18	0.64	59.62
2	Flexibility	16.67	78.85	19.87	69.87
3	Originality	32.05	88.46	21.79	69.87
4	Elaboration	0.64	82.05	0.64	69.23
	Average score	12.50	77.88	10.74	67.15
	SD	8.72	9.23	7.50	11.22

Improvement for every aspect of creative thinking was also identified to get a better understanding about the effect of RME-based e-module for every aspect (see Table 4).

Table 4. Improvement or gain for every aspect of critical thinking

No	Aspect	Gain	
		Experimental Group (RME-based e-module)	Control Group (RME with paper-and-pencil)
1	Fluency	61.54	58.98
2	Flexibility	62.18	50.00
3	Originality	56.41	48.08
4	Elaboration	81.41	68.59

The indicator of creative thinking that experienced the highest increase in both the experimental class and the control class was the elaboration indicator. This indicator experienced the greatest increase, namely 81.41% in the experimental class and 68.59% in the control class. The elaboration indicator relates to the student's ability to provide a detailed and detailed explanation of the problem given. The data in Table 4 indicates that the elaboration indicator is an indicator of creative thinking which was easier to develop in learning using RME-based e-Module and using RME approach with paper-and-pencil activities.

The indicator of creative thinking which has the highest average in the experimental class is an indicator of originality, while in the control class is an indicator of originality and flexibility. The average originality indicator in the experimental class was 5.31 and, in the control class the average flexibility and originality indicators were the same, namely 4.19. The average flexibility indicator in the control class is 4.19. The data in Table 4 indicates that flexibility and originality indicators are indicators of creative thinking which were easier to develop in learning using RME-based e-Module and using RME approach with paper-and-pencil activities. Table 4 also shows that the indicator of creative thinking which had the lowest average is the fluency indicator with an average of 3.73 in the experimental class and 3.58 in the control class. The originality indicator relates to problem solving abilities that are different from others or pure problem-solving ideas from new/unique personal thoughts. The data in Table 4 indicates that the fluency indicator is an indicator of creative thinking which was more difficult for students to develop through RME-based e-Module and using RME approach with paper-and-pencil activities compared to other indicators of creative thinking ability.

With respect to the level of students' creative thinking, all students in the experimental group were at the low prior to the classroom intervention. After learning mathematics by using RME-based e-module, students' creative thinking increased. Half of the students were at the medium category, 26.92% of students were at the high level, and 11.54% of students were categorized as very high level. Prior to the classroom intervention, all students in the control group were at the low level. After the intervention, 34.62% of the students were categorized as medium level and 11.54% students achieved high level. However, none of the students in the control group could achieve very high level. See Table 5 for the complete results.

Table 5. The levels of students' creative thinking before and after classroom intervention

Score Interval	Experimental Group				Control Group				Category
	Pretest		Posttest		Pretest		Posttest		
	f	%	*f*	%	*f*	%	*f*	%	
90 <x≤100	0	0%	3	11.54%	0	0%	0	0.00%	Very high
80<x ≤90	0	0%	7	26.92%	0	0%	3	11.54%	High
70<x≤80	0	0%	13	50.00%	0	0%	9	34.62%	Moderate
x <70	26	100%	3	11.54%	26	100%	14	53.85%	Low

The effect of RME-based e-module on students' creative thinking

The aim of this study was to investigate the effect of RME-based e-module on students' creative thinking. Therefore, the data analysis tested the hypothesis whether students who learned mathematics with RME-based e-module performed better than students who learned mathematics by using RME with paper-and-pencil activities. The two sample t-test revealed that In the t value was 3.694 and the significance value was 0.001. It means that the value of Sig. 0.001 <0.05, so that it can be concluded that the creative thinking of students in the experimental group significantly had a significantly better improvement than the creative thinking of students in the control group.

This information shows that the learning that employes RME-based e-module has a better positive effect on improving students' creative thinking than the learning which uses RME approach with paper-and-pencil activities. This statement is supported by the results of the independent sample t-test which shows that there is a significant difference in the average mathematical creative thinking ability between the two learning classes and information regarding the acquisition of the average mathematical creative thinking ability in classes using RME-based e-module than the class using RME approach with paper-and-pencil activities. The integration of RME approach into e-module platform can improve students' creative thinking. This finding is in agreement with a study conducted by Risma and Yulkifli (2020) and Ruqoyyah et al. (2020) that learning that integrates e-modules can develop 21st century skills including creative thinking.

CONCLUSION

This study confirms that learning mathematics that uses RME-based e-module has a significantly better effect on the improvement of students' creative thinking than the learning of mathematics which uses RME with paper-and-pencil activities. This statement is supported by the results of the independent sample t-test which shows that there is a significant difference in the average mathematical creative thinking ability between the two learning classes and information regarding the acquisition of the average mathematical creative thinking ability in classes using RME-based e-module is higher than the class using RME with paper-and-pencil activities. There are two components of RME-based module which correspond to the improvement of students' creative thinking. This aspect is the digital platform of the e-module which offers students more opportunity to do mathematical exploration. The digital feature of e-module could also give students a quite instant feedback on their works so that students can guide students toward next activities. The positive effect of digital platform also highlighted by other previous studies. The study of Yusuf et al. (2020) that found the positive effect of e-modules on students' Higher Order Thinking Skills (HOTS). In a broader scope, Sukestiyarno and Hartutik (2020) revealed that e-module can effectively improve students' problem-solving skills. The second component of RME-based e-module that contributes to students' creative thinking is Realistic Mathematics Education approach. RME sees mathematics as human activity in which students actively construct their mathematical understanding through phenomenological exploration and progressive mathematization. Such activities could lead students to explore various strategies and invent new ideas. Exploring various strategies and inventing new ideas are essential aspects of creative thinking. The positive effect of RME on students' mathematical creativity has also been revealed by Ndiung et al. (2020), Royhana et al. (2021), and Ismunandar et al. (2020).

The finding of this study suggests teachers facilitate students to develop students' creative thinking in mathematics by developing and implementing electronic teaching materials. With such a platform students can actively get involved in the learning process so that their creative thinking skills can also increase. Providing students with contextual problems as used in RME could also facilitate the development of students' creative thinking because such problems are mostly open and could lead to exploring various strategies.

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