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Computer-Assisted Realistic Mathematics Education for Enhancing Students' Higher-Order Thinking Skills

(Experimental Study in Junior High School in Palembang, Indonesia)

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Abstract

The aim of this study is to assess the differences of students' achievement and enhancement in higher-order thinking skills who worked under computer-assisted realistic mathematics education (CA-RME) and RME only. It was an experimental research with Pretest-Posttest Two Treatment Design. Higher-order thinking skills test is the instrument that was used in this study. The data were analyzed by using t-test, Mann-Whitney test, and two-way ANOVA. Based on the data analysis, the conclusions are: (1) there were differences in the achievement of higher-order thinking skills between students who worked under CA-RME and RME only; and (2) there was no different enhancement between students' high-order thinking skills who worked under CA-RME and RME only.

Keywords: higher-order thinking skills, computer-assisted, realistic mathematics education.

1. Introduction

Thinking skills are part of the intellectual human cognitive processes (Wilson, 2000). Thinking skills are indispensable to everyone including students as a preparation in facing the global era, advances in information technology, the convergence of science and technology, as well as the rise of the creative industries in the future (The Public Test of Materials of Curriculum 2013). Thinking skills described above can be developed through education and learning. Through practicing in learning, students will able to acquire, manage, analyze, synthesize, and utilize the information to achieve a purpose or find settlement of difficult situations.

Based on the description above, there is a relationship between a person's thinking skills and ability to survive when they face a challenge. The better a person's thinking skills, the better the ability to resolve problems encountered and the greater the potential to survive and win in the global competition and become a good problem-solver.

The preliminary studies indicate that more than 50% of students were not able to analyze, synthesize information, and make conclusion (Susanti, 2012). This description reinforces the results of Programme for International Student Assessment (PISA) in 2009 and PISA in 2012, which indicate that less than 10% of Indonesian students cannot solve problems that requiring complex thinking. It also indicates a lack of mathematical ability and higher-order thinking skills in Indonesian students.

Higher-order thinking skills is the ability of students in using critical and creative thinking skills (Dewanto and Sumarmo, 2004) through some activities such as: analyze, synthesize, produce, integrate, evaluate and create (Anderson and Kratwohl, 2001).

Previous research suggests that there are several learning activities that can enhance students' higher-order thinking, such as: (1) technology-enriched environment (Handa, 2000) and (Hapson, 2002), (2) computer-assisted learning (Cotton, 1991), (3) learning in small groups, peer tutoring, cooperative, collaborative (Tobin, Capie and Bettencourt, in King; 1998); (4) books (teaching materials) and additional guidance is more emphasis on information gathering activities, remembering, and organizing skills (Shepard, 1989), (5) inquiry learning (Haugh, 2002), (6) Scaffolding (Slavin, 1995).

To overcome those problems, computer-assisted realistic mathematics education (CA-RME) could be implemented as an alternative strategy. CA-RME is learning process that integrate realistic mathematics education and computer-assisted learning approach, so that the delivery of contextual mathematical topic, guieded process, mathematization or development of models which are the principle of the RME (Gravemeijer, 1994) are done using computers. In addition, the process of learning and teaching materials used are also in accordance with the characteristics of the RME (Gravemeijer, 1994 and Zulkardi, 2005), namely: (1) using the contextual issues; (2) using the model; (3) using the students' contributions; (4) the interaction in the learning process; and (5) using a variety of relevant learning theory, interrelated, and integrated with other learning topics. All of these activities have greater potential to enhance students' in higher-order thinking skills.

Based on theories above, the problem formulation in this research is "Can computer-assisted realistic mathematics education enhance students' higher-order thinking skills?".

Furthermore, the problem formulation above can be described in several sub problem formulations, as follows:

1. Are the achievement and enhancement of students' higher-order thinking skills who worked under CA-RME as good as the students who worked RME only?
2. Are the achievement and enhancement of students' higher-order thinking skills who worked under CA-RME as good as the students who worked RME only based on their school-levels (high and medium)?
3. Are the achievement and enhancement of students' higher-order thinking skills who worked under CA-RME as good as the students who worked RME only based on their school-levels (high and medium)?

2. Research Methodology

2.1 Research Design and Sample

This study is an experimental research with Pretest-Posttest Two Treatment Design (Cohen et al., 2007). In this reseach design, the students in experimental group worked under computer-assisted realistic mathematics education, and the student in control group worked under realistic mathematics education only. Besides that, before and after learning process, the students had pretest and posttest. The following figure represents the experimental design of the research:

E:	O	X_1	O
C:	O	X_2	O

Where, E = experimental group

C = control group

O = pretest or posttest

X_1 = computer-assisted realistic mathematics education

X_2 = realistic mathematics education

The sample in this study is 185 Junior High School students (grade IX) in Palembang city, comprising 97 students in experimental group and 88 students in control group. Based on their school-level, it consists of 53 students from higher-level school and 135 students from medium-level school.

This study used non-probability sampling with purposive sampling technique. Sample selection is based on the following considerations:

- Schools that have accreditation rank A or B.
- The willingness of the schools (especially principals and teachers) to cooperate in this research.
- Schools have sufficient computer facilities.

2.2 Research Instruments

There are two instruments that used in this research. They are prior mathematical knowledge test and higher-order thinking skills test. Prior knowledge tests were performed to obtain an overview of students' knowledge about the materials that have been owned by students' former. This prior knowledge has been used to construct their concept and knowledge when they worked under CA-RME. Its results were used to determine the equality of students' prior knowledge between students who worked under CA-RME and RME only.

Pretest-posttest instrument was used to measure the students' higher-order thinking skills before and after learning process. Pre-test and post-test instruments was adopted and modified from the questions in PISA 2003, 2006 and 2009, because those questions can illustrate the students' higher-order thinking skills.

2.3 Data Analysis

The data from students' prior knowledge were analyzed using statistical tests. Statistical test was used to see the differences in students' prior knowledge as a whole and for every school-levels. All of data tests were analyzed qualitatively and quantitatively. The qualitative analysis used statistical test and the quantitative one used descriptive data in forms of categories, as the following table.

Table 1. Achievement Categories of Students' Higher-Order Thinking Skills

Score	Categories
$90 \leq$ Score ≤ 100	Very good
$75 \leq$ Score < 90	Good
$55 \leq$ Score < 75	Enough
$40 \leq$ Score < 55	Less
Score < 40	Poor

3. Finding and Discussion

This chapter represents an overview about implementation CA-RME, achievement and enhancement of higher-order thinking skills between students who worked under CA-RME and RME only.

3.1 Equality Students' Prior Mathematical Knowledge (PMK)

Previously, it was stated that PAM tests were used to determine the equality of students' prior knowledge. These results of test were used as a reference to: (1) classify students in experimental group and control group, (2) classify students into three categories: lower, middle, and top. Students in experimental and control group had the equal knowledge and ability before worked under CA-RME and RME only. Analysis of students' prior knowledge represented this table.

Table 1. Analysis of Students' Prior Mathematical Knowledge

School Levels	CA-RME	RME	Statistics Test	
			Sig.	Interpretation
Whole	8.29	8.71	0.577	There were no differences
High	10.92	10.81	0.930	There were no differences
Middle	7.32	7.77	0.515	There were no differences

Notes: maximum score = 20

Based on Table 2 above, the value of significance (sig.) was more than $\alpha = 0.05$ in all aspect. It means that H_0 is accepted. Thus, it can be concluded that there is no difference in PMK between students who worked under CA- RME and student who worked RME only.

3.2 Analysis Students' Higher-Order Thinking Skills

This section was aimed to describe and compare students' achievement and students' enhancement in higher-order thinking skills. The analysis was based on a whole learning approaches (CA-RME and RME only), and school-levels (high and medium).

3.2.1 The Achievement and Enhancement of Students' Higher-Order Thinking Skills

The students' achievement in higher-order thinking skills as whole and based on school-levels are discussed. The achievement reflects to student's knowledge of material that has been taught. It is reflected on the post-test scores. The following figure represents students' achievement in higher-order thinking skills.

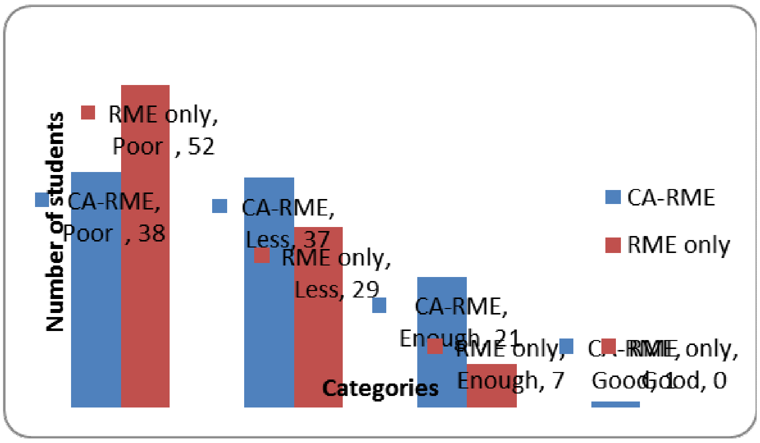

Figure 1. Students' Achievement in Higher-Order Thinking Skills

Based on Figure 1, there are differences in the achievement of students' higher-order thinking skills between students who worked CA-RME and RME only at poor, less, and enough category. Beside that, number of students who worked under CA-RME are more than RME only for less or enough category. It means CA-RME can enhance achievement of students' higher-order thinking skills. The description of students' higher-order thinking skills as overall were represented in Table 3.

Table 3. Description of Students' High-Order Thinking Skills

School Levels	Learning	Pre-test		Post-test		<g>		n
		Mean	SD	Mean	SD	Mean	SD	
Whole	CA-RME	3.10	13.16	42.81	13.55	0.15	0.19	97
	RME	29.48	11.52	37.56	12.19	0.11	0.11	88
High	CA-RME	33.12	13.75	42.88	10.80	0.12	0.20	26
	RME	29.41	10.33	38.00	10.17	0.13	0.08	27
Middle	CA-RME	30.36	12.95	42.78	14.49	0.16	0.19	71
	RME	29.51	12.10	36.92	13.01	0.10	0.12	61

Statistical test: Mann-Whitney test.

Table 3 above indicates that there were difference achievement and enhancement in students' high-order thinking skills between student who worked under CA-RME and RME only. To find out the differences, the following formulations of hypotesis are proposed:

H_o : $\mu_1 = \mu_2$ There were no differences achievement and enhancement in students higher-order thinking skills.

H_a : $\mu_1 \neq \mu_2$ There were differences achievement and enhancement in students higher-order thinking skills.

Testing criteria used: if the value of significance (sig.) is more than $\alpha = 5\%$, then H_0 is accepted; otherwise, H_0 is rejected. The result of statistical test is represented in Table 4.

Table 4. The Result of Statistical Test of Students' Achievement and Enhancement in Higher-order Thinking Skills

Data	School Level	Statistic Test	Sig.(2-tailed)
Achievement	Whole	t-test	0.006
	High	Mann-Whitney test	0.182
	Middle	t-test	0.017
Enhancement	Whole	Mann-Whitney test	0.390
	High	Mann-Whitney test	0.845
	Middle	Mann-Whitney test	0.242

Based on the analysis above, it can be concluded that: (1) In high-level school, there were no difference in the achievement of higher-order thinking skills between students who worked under CA-RME and RME only; (2) In all school levels, there were differences in terms of achievement of higher-order thinking skills between students who worked under CA-RME and RME only; (3) In all school levels, there were no differences in terms of enhancement of higher-order thinking skills between students who worked under CA-RME and RME only; (4) School level affected the achievement of students' higher-order thinking skills; and (5) School level did not affect the students' enhancement in higher-order thinking skills.

3.2.2 Interaction between Learning Approach and School Levels to Enhance Students' Higher-Order Thinking Skills

The interaction between learning factors and school-levels toward the students' higher-order thinking skills was discussed here. To see this interaction, two-way ANOVA was used in this research. Table 4 below represents two-way ANOVA.

Table 5. Two-Way ANOVA Test of Higher-Order Thinking Skills

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	0.129(a)	3	0.043	1.698	0.169
Learning	0.022	1	0.022	0.852	0.357
School Levels	0.001	1	0.001	0.050	0.823
Learning * School Levels	0.053	1	0.053	2.106	0.148
Error	4.575	181	0.025		
Total	8.023	185			

Based on Table 4 above, it can be concluded that: (1) There was no differences in higher-order thinking skills between students who worked under CA-RME and RME only; (2) There was no difference in higher-order thinking skills in whole school-levels; (3) Learning factors and school-levels gave effect to the students' higher-order thinking skills as a whole.

Table 4 shows that the interaction score of learning factors and school-levels factors were 2.106 and its significance was more than 0.05. It can be concluded that there was interaction between learning factors and school-levels factor in enhancing students' higher-order thinking skills. This following figure represents this interaction.

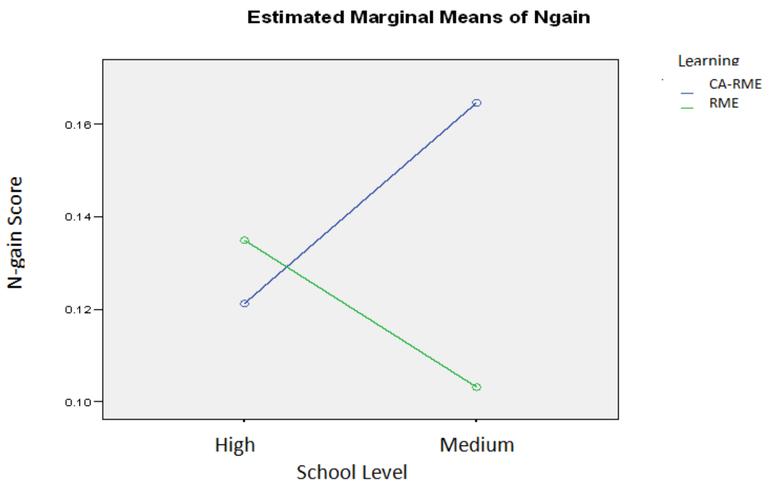

Figure 2. The Interaction of Learning Approach and School Levels in Enhancing Students' Higher-Order Thinking Skills.

3.3 Discussion

This section is focused on students' difficulties who faced solving higher-order thinking skills problems. The most of difficulties are: (1) reading and interpreting the data, (2) making interpolation and representation in other forms from the data; and (3) making conclusions and providing argument that supporting conclusions.

The inability of students is influenced by several factors such as:

- Students do not understand the concept and the students have not been able to use mathematical concepts they have learned to problem solving. Kostolan (2009) suggested that students who do not understand the concept tend to experience conceptual error, for example: mistakes in interpreting, using the term both concepts and principles in problem solving.
- Knowledge of the students are still not complete. Widiharto (2008) suggested that incomplete knowledge may cause difficulties and errors in solving math problems.
- Students are not able to synthesize and combine the existing information to support completion. Understanding only piece of concept, tend to make students experience difficulties in solving complex problems. Jonassen (2004) suggested that one of the keys to success in solving the problem is not only seen from its ability to accurately represent problem solving, but also seen on the ability of students to understand the problem well, the ability to identify appropriate strategies to solve these problems, as well as the ability and skill in doing arithmetic arithmetic to solve the problem.

Those students' difficulties are caused by different school levels and prior knowledge, but those problems can be solved by making groups discussion, collaboration, cooperation and other interaction among students who have low-ability and higher-ability. Discussion, collaboration, cooperation and other interaction in learning process have more potential to develop students' higher-order thinking skills (Tobin, Capie and Bettencourt, in King; 1998).

From the research finding, it can be concluded that there was no different higher-order thinking skills between the students who worked under CA-RME and RME only, but based on the quality of students' answers they constructed when solving higher-order thinking skills problems, the students who worked under CA-RME have better answers and more complete in arguments or conclusions than the students who worked under RME only. The following figures are examples of the students' answers:

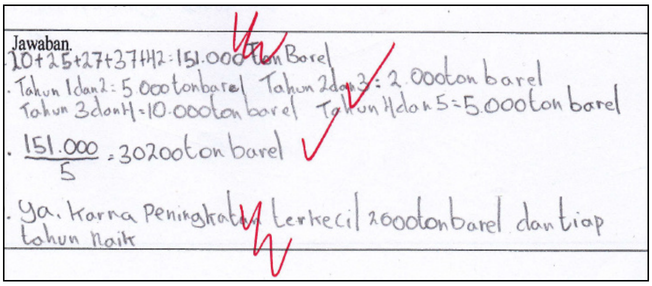

Figure 3. The Students' Answer in Experimental Group

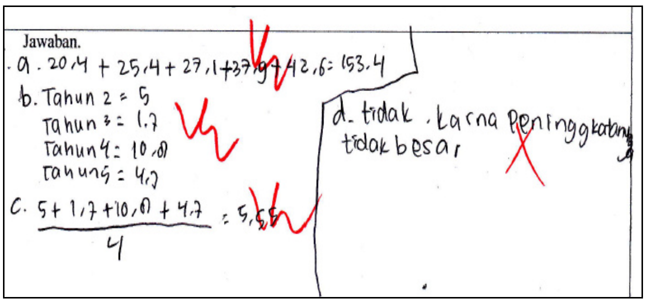

Figure 4. The Students' Answer in Control Group

From the depth and breadth of material when the problems were answered, there were different strategies between students who worked under CA-RME and RME only. Students who worked under CA-RME give answer a more detail. Beside that, the concepts were used to complete the answer was also much better, and the strategies used to solve are the problems also more precise.

Another problem when working under CA-RME were difficulties in managing time and too much contextual issues presented in learning materials. It causes teachers have no enough time to discuss all of contextual issues.

Other causes is the use of computers in learning segment. In this situation, sometimes the teacher was not only teaching mathematical concepts, but also have to be involved in operating computers. In addition, students who can operate computers, sometimes have to teach their friends in operating the computer.

All of problems above are consistent to weakness realistic learning theories that argued by Hadi (2002). They suggests that realistic learning has some difficulties, such as: (1) searching contextual issues that are not too easy for any math topic that needed in learning; (2) assessment and learning mathematics realistic more complicated than conventional learning; and (3) the selection of media should be careful and should be able to help the students in thinking process.

4. Conclusions

Based on the results above, it can be concluded that "There was no difference in achievement and enhancement in higher-order thinking skills between students who worked under CA-RME and RME only".

Based on the conclusion, the following sub conclusions can be described: (1) There were differences in achievement of higher-orderl thinking skills between students who worked under CA-RME and RME only; (2) At the high school-level, there was no difference in achievement of higher-order thinking skills between students who worked under CA-RME and RME only; (3) At the middle school-level, there was differences in the achievement of higher-order thinking skills between students who worked under CA-RME and RME only; (4) At the all school-level , there was no difference in enhancement of higher-order thinking skills between students who worked under CA-RME and RME only; and (5) There was interaction between learning factors and school-levels factor in enhancing students' higher-order thinking skills.

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