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MATHEMATICAL CRITICAL THINKING ABILITY AND DISPOSITION

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Abstract

This study is a pretest-postest experiment control group design having a goal to analyze the role of scientific approach on mathematical critical thinking ability and disposition. The study involved 70 eleventh grade of vocational high school students, a test on mathematical critical thinking, a disposition scale, and a scale of students' perception on scientific approach. The study revealed that students getting treatment on scientific approach attained better grades on mathematical critical thinking ability and disposition than that of students taught by expository teaching, though the mathematical critical thinking ability grades were at medium level and the grades of disposition were at fairly good level. Besides that, students performed positive opinions toward scientific approach and there was association between mathematical critical thinking ability and disposition.

Keywords: mathematical critical thinking ability, mathematical diposition, scientific approach, perception toward scientific approach.

Abstrak

Penelitian ini adalah suatu eksperimen dengan disain pretes-postes dan kelompok kontrol yang bertujuan menelaah peranan pendekatan saintifik terhadap kemampuan berpikir kritis dan disposisi matematik. Penelitian melibatkan 70 siswa kelas 11 SMK, tes kemampuan berpikir kritis matematik, skala disposisi, dan skala persepsi siswa terhadap pendekatan saintifik. Penelitian menemukan bahwa siswa yang mendapat pendekatan saintifik mencapai mutu berpikir kritis matematik yang lebih baik dari pada siswa yang mendapat pembelajaran konvensional. Namun, mutu kemampuan berpikir kritis matematik siswa pada kedua kelas tergolong sedang dan mutu disposisi siswa tergolong cukup. Selain itu, siswa menunjukkan persepsi yang baik terhadap pendekatan saintifik dan terdapat asosiasi antara kemampuan berpikir kritis dan disposisi matematik.

Kata Kunci: berpikir kritis matematik, disposisi matematik, pendekatan saintifik, persepsi terhadap pendekatan saintifik

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INTRODUCTION

Mathematical critical thinking ability and mathematical diposition are two important components of mathematics learning outcomes that should be improved on high school students. That statement is in line with the goals of mathematics teaching-learning process. The goals among others are: a) to posess logical, critical, creative, innovative thinking, and self learning abilities; b) to demonstrate critical, creative, accurate, objective, opened thinking, self confidence, curious, interest, persevere, persistent attitudes; c) to appreciate the beauty and the usage of mathematics in daily life (Kurikulum 2013).

Some experts define the term of critical thinking differently, however it contains similar meaning. Capie and Ennis (Baron, and Sternberg, (Eds), 1987) define critical thinking as a reasonable reflective thinking and focussed on trusted activities. Critical thinking relates to five key ideas such as practical, reflective, reasonable, trusty, and action. Besides that, critical thinking has four components namely: clarity, bases, inference, and interaction. Other expert, Gokhale (1995), defines critical thinking as thinking involves some activities such as to analyze, to syntesize, and to evaluate concepts. Especially in mathematics, Glaser (2000) explaines that mathematical critical thinking involves abilities and disposition which combined with prior knowlegde, reasoning, cognitive strategy for generalizing, proving, and evaluating a mathematical situation reflectively.

Observing those experts' definitions of critical thinking (Ennis, as cited in Baron, and Sternberg, (Eds), 1987, Gokhale, 1995, Glaser, 2000), in fact, critical thinking is one of mathematical high order thinking that is not only to memorize but also to manipulate learning materials into a new situation as well. However, critical thinking is not equivalent to high order thinking skills. Critical thinking involves a disposition and all of high order thinking components but conversally high order thinking not always contain disposition (Sumarmo, 2010). Furthermore, Ennis (Baron, dan Sternberg, (Eds), 1987) explain in detail about indicators of critical thinking as follow: a) to focuss on the question; b) to analyze and to clarify questions, responses, and arguments; c) to consider trusted sources; d) to deduce and to analyze deduction; e) to induce and to analize induction; e) to formulate explanation, hypothesis, and conclusion; f) to interact with other person.

Refering to Glaser' conception (2000), therefore mathematical critical thinking involves abilities and mathematical disposition. Polking (Sumarmo, 2010) proposes that disposition is desire, awareness, tendency, and strong dedication for thinking and doing mathematics positively. Others experts define the term of disposition in similar meaning such as: a) mathematical disposition is positive attitude and habits to regard that mathematics as logical, workable, and useful subject (Kilpatrick, Swafford and Findel, as cited in Hendriana and Sumarmo, 2014); b) Disposition contains three processess such as: self-observe, self-evaluation, and self-reaction (Bandura, 1997, as cited in Hendriana and Sumarmo, 2014). Furthermore, Polking (Sumarmo, 2010) and NCTM (2000) detail the indicator of disposition as follow: a) Being self confident in doing mathematics, reasoning, and communicating mathematical ideas; b) Being flexible in exploring mathematical ideas and trying alternative solution of problem; c) Being persistence, interested, and curious in doing mathematics; d) Tending to monitor, to reflect their own performance and reasoning; e) Evaluating aplication of mathematics into other mathematics situation, and daily life; and f) Having appreciation to the role of mathematics in culture and value, and mathematics as a tool and as a language.

Mathematics Curriculum in Indonesia (Kurikulum, 2013) suggests that mathematical hard-skill such as mathematical critical thinking ability and mathematical soft-skill as mathematical disposition should be developed simoultaneously and proportionally. Moreover, Polya (1973) stated that teacher's role not only to deliver information but the most important things were: to have position as students, to understand what students think, to help students to think and to learn to construct their knowledge. Those opinions describe constructivism philoshopy which its characteristics: a) student active learning, b) information was related to previous students' knowledge in order to form meaningfull and more complex knowledge; c) learning activities were oriented to investigation and invention.

One of teaching-learning approach which in line with suggestion of Curriculum 2013, Glasser's definition of critical thinking, and Polya's statement on teacher' role, is scientific approach. Mathematics curriculum of Indonesia (Kurriculum 2013, as cited in Permendikbud, 2013) proposed that scientific approach has five phases namely: observing, questioning, data collecting, associating, and communication. In observing phase, student excercises to choose and ditermine relevant data from a series of data; then in questioning phase, student trains to compile question from the relevant selected data; afterwards in data collecting phase, student practices to collect data for answering the compiled question; then in associating phase student tries to associate and to verify the answer to the prior or original problem; afterwards, in communicating phase, student practices to communicate their solution to all of students in the class or to other member in their working group. From actvities in all phases, it is estimated that scientific approach gives student opportunity to improve his or her mathematical critical thinking ability. Beside that, scientific approach allows student an opportunity for improving her or his mathematical disposition.

This moment, report of study on critical thinking ability using scientific approach is still limited. Even if, some studies (Ambarwati, 2011, Ibrohim, 2015, Jayadipura, 2014, Kurniati, Kusumah, Sabandar, Herman, 2015, Palinusa, 2013, Sinurat, 2014, Tamsil, 2016), reported that on mathematical critical thinking ability, students getting treatment with various innovative mathematics approaches obtained better grades than that of students taught by expository teaching. But, the students' grades on mathematical critical thinking ability were still at low-medium level. Likewise, a lot of studies (Abdurahman, 2014, Bernard, and Rohaeti, 2016, Choridah, 2013, Herdiana, 2016, Ibrohim, 2015, Isnaeni and Maya, 2014, Pradhini, 2016, Qodariyah and Hendriana, 2015, Sinurat, 2014, Sugilar, 2013, Suharsono, 2015, Suheri, 2014, Sumarmo, Hidayat, Zulkarnaen, Hamidah, Sariningsih, 2012) reported that various inovative teaching approaches lead student to attain fairly good grades on mathematical disposition. Seemingly, mathematical critical thinking ability is one of difficult mathematical higher order thinking for high school students. While on mathematical disposition, before students involved in this study they had learning experience from prior mathematics teaching, so that they posessed medium-fairly good grade on mathematical disposition.

The aforementioned argument, motivate researchers to carry out a study for improving students' mathematical critical thinking ability and mathematical disposition using scientific approach. Further, refering to those afforementioned arguments, researchers formulate problem of this study as follow:

a) Are the grades of mathematical critical thinking ability and its Normalized Gain (N-Gain), and mathematical disposition of students getting treatment with scientific approach better than the grades of students taught by expository teaching?

b) Is there any association between mathematical critical thinking ablity and mathematical disposition in scientific approach class?
c) What kinds of difficulties do students meet in solving mathematical critical thinking tasks in both classess?
d) What is students' perception toward the implemented scientific approach?

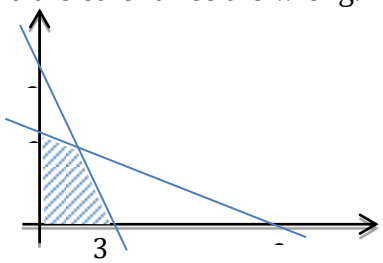
Method and Design of Study

This study is a pre test-post test experimental control group design which having a goal to analyze the role of scienctific approach on students' mathematical critical thinking ability and mathematical disposition. The study involved 70 eleventh grade Vocational High School students, an essay mathematical critical thinking test, a mathematical disposition scale, and a perception on scientific approach scale. The mathematical critical thinking ability test consisted of 5 items, and using Hendriana and Sumarmo (2014) and Sumarmo (2015) as references it was obtained charactristic mathematical critical thinking ability as follow: reliability test was 0.69; item validity were $0.46 \leq IV \leq 0.83$; discriminat power were $0.23 \leq DP \leq 0.81$, and difficulty index were $0.11 \leq DI \leq 0.44$.

Further, the data were analized by using SPSS for computing mean, standar deviation, percentage of data; testing normality and homogeneous of data, testing hypothesis of mean difference, and of existency of association between two variables.

In the following, we attached sample items of mathematical critical thinking test, sample of mathematical disposition, and sample item of perception on scienctific approach scale.

1. **Sample item of mathematical critical thinking** (To examine the truth of an argument)
   A baker has a stock on hand the main ingredients for making cake: 16 ounces wheat flour, 11 ounces white sugar, and 15 eggs. Cake 1 needs 1 ounce wheat flour, 2 ounces white sugar, 3 eggs. While cake 2 needs : 2 ounce wheat flour, 1 ounces white sugar, 1 egg. From selling cake 1 and cake 2, the baker will get profit Rp 8.000,00 dan Rp 6.000,00. Successesively. For getting maximum profit, the baker determines to bake 4 cakes 1, and 3 cakes 2. Examine the truth of the baker's descision. Explain your answer.
2. **Sample item of mathematical critical thinking test** (To explain situation accompanied with explanation)
   Which one of the four inequality system below is fit to the figure. Explain why your choice is true and the other three are wrong.



A. $x + 3y \leq 6; 3x + y \geq 3; x \geq 0; y \geq 0$
B. $x + 3y \geq 10; 2x + y \leq 3; x \geq 0; y \geq 0$
C. $2x + 3y \leq 6; 2x + y \geq 3; x \geq 0; y \geq 0$
D. $x + 3y \leq 6; 2x + y \leq 3; x \geq 0; y \geq 0$

3. Sample item of Mathematical Disposition Scale

No.	Statement	SA	A	DA	SDA
1.	I am sure able to solve difficult mathematics taks (+)				
2.	I avoid mathematical tasks which different with teacher's examples (-)				
3.	I am curiuos to confront difficult mathematical task. (+)				
4.	I compare my mathematics work with my friend's solution (+)				
5.	I am pessimis could overcome my learning difficulties in mathematics (-)				
6.	I avoid to pose question and mathematics idea when learning in working in small discussion. (-)				

4. Sample item of perception on Scienctific Approach Scale

Note: SA : strongly agree DA : disagree
A : agree SDA : strongly disagree

No	Statement	SA	A	DA	SDA
1.	Exercises in the students worksheet release students, to choose their own way on solving them.				
2.	Explanation in the students worksheet make students to be confused.				
3.	The mathematics teaching improve student's disposition .				
4.	The analysis in the students' worksheet make students lazy.				
5.	Problems and questions in the students' worksheet train students work persistently.				
6.	The teaching process restricts students to select exercise problems .				

Findings and Discussion

Description of mathematical critical thinking ability and its gain, mathematical disposition and perception toward scientific approach of students are attached in Table 1.

Table 1
Description of Mathematical Critical Thinking Ability, Mathematical Disposition and Perception Toward Sienctific Aproach of Students

		Sienctific Approach				Expository Teaching (ET)			
Variables	Stat	Pre-Test	Post-Test	N Gain	N	Pre-Test	Post-Test	N Gain	N
	$\bar{x}$	11.71	50.49	0.44		10.00	40.80	0.17	
MCTA	%	11.71	50.49		35	10.00	40.80		35
	SD	8.69	17.16	0.18			19.28	0.16	
MD	$\bar{x}$	-	100.57	-		-	97.43	-	
	%	-	69.82	-	35	-	67.66	-	35
	SD	-	7.7P	-		-	7.25	-	
PSA	$\bar{x}$	-	125.1		35				
	%	-	73.59						

Note
MCTA : Mathematical Critical Thinking Ability, Ideal Score : 100
MD : Mathematical Disposition Ideal Score : 144
PSA : Perception Toward Scientific Approach Ideal Score : 170

From Table 1, in pre-test it was found that there was no difference students' grades on mathematical critical thinking ability in both teaching approaches and the grades were very low level. Nevertheles, after learning process, on mathematical critical thinking ability and its gain (N<G>), students getting treatment with scientific approach attained better grades (50.49 % out of ideal score, N<G> 0.44) than the grades of students taught by expository teaching (40.80% out of ideal score, N<G> 0.35). Similar finding on mathematical disposition students taught by scientific approach (69.82% out of ideal score) obtained better grade than student taught by expository teaching (67.66% out of ideal score). Students' mathematical disposition were at fairly good level. The testing hypotesis of those data was attached in Tabel 2.

Table 2
Testing Hypothesis Of Mean Difference of Mathematical Critical Thinking Ability, And Mathematical Disposition, on Both Teaching Approaches

Variables	Teaching Approach	$\bar{x}$	SD	N	Sig (2-tailed).	Sig (1-tailed).	Interpretation
MCTA	SA	50.49	17.16	35	0.030	0.015 <	$MCTA_{SA} > MCTA_{ET}$
	ET	40.80	19.28	35		0.05	
N-Gain	SA	0.59	0,16	35	0.056	0.028 <	N-Gain $MCTA_{SA} >$
MCTA	ET	0.29	0.16	35		0.05	N-Gain $MCTA_{ET}$
MD	SA	100.23	8.89	35	0.038	0.019 <	$MD_{SA} > MD_{ET}$
	ET	94.11	8.12	35		0.05	

Note: MCTA : Mathematical Critical Thinking Ability Ideal score :100
MD : Mathematical Disposition Ideal score :160

Those findings were similar to the findings of other studies (Ambarwati, 2011, Ibrohim, 2015, Koswara, 2017, Mulyani, 2017, Tamsil, 2016) that various innovative teaching approaches took better role than expository teaching on improving mathematical critical thinking ability. Even though, those student's grades of mathematical critical thinking ability were still at low-medium level. Likewise, a lot of studies (Abdurahman, 2014, Bernard and Rohaeti, 2016, Choridah, 2013, Eriska, 2017, Herdiana, 2016, Ibrohim, 2015, Isnaeni and Maya, 2014, Pradhini, 2016, Qodariyah and Hendriana, 2015, Ruhiyat and Sugandi, 2017, Sugilar, 2013, Suharsono, 2015, Suheri, 2014) on mathematical disposition reported similar findings that students getting treatment with innovative teaching approaches attained better grades than students taught by expository teaching, and grades were at fairly good level. Even if, those findings were different with the findings of other studie such as of Sinurat (2014) and Sumarmo, et.al. (2012) which reported that there were no difference on students'grades of mathematical disposition.

Besides those positive findings on the role of scientific approach, this study found that students' perception on scientific approach was at fairly good level (73.59% out of ideal score). They performed positive perception toward implementation of scientific approach. Some of positive perception among other things were: Exercises problems in the students worksheet release students to choose their own way to solve; The mathematics teaching improve students'self confidence; Problems and questions in the students' worksheet train the students work persistently; Problems in students' worksheet train students look for various ways of solution; Teaching environment motivate students mathematical disposition. Those positive students' perception on scientific approach in this study was similar to findings of other studies such as Koswara (2017) and Mulyani (2017).

Further analysis, was concerning association between mathematical critical thinking ability and mathematical disposition. That association was analyzed by using contigency table such as in Table 3 and by using $\chi 2$ testing (Table 4).

Table 3
Contingency Table of Mathematical Critical Thinking Ability And Mathematical Disposition in Scientific Approach Class

MCTA \ MD	High	Medium	Low	Total
High	6	0	0	6
Medium	1	11	0	12
Low	0	16	1	17
Total	7	27	1	35

Table 4
Test of Pearson-Chi Square and Contigency Coefficient between Mathematical Critical Thinking Ability and Mathematical Disposition

Pearson-Chi Square (χ^2)	DF	Contigency Cofficient (C)	Sig.(2-tailed)
30.067[a]	4	.680	0.000

Based on Table 3 and Table 4 it were found contigency coefficient C = .680 and $\chi 2$ = 30.067 with sig (2-tail 0.000 < 0.05). It implied that there was high association (Q = 0.833) between mathematical critical thinking ability and mathematical disposition (after C = .680 compare to Cmax= 0.816).

This findings of association between mathematical critical thinking ability and affective learning outcomes of this study was similar to findings of other studies such as Jayadipura (2014) and Mulyani (2017). But, those findings was different with findings of other studies (Koswara, 2017, Sinurat, 2014, Sumarmo, et al, 2012) that there were no association between mathematical critical thinking ability with affective mathematics learning outcomes. Those findings indicated that there were incosistent findings on the existence of association between mathematical critical thinking ability and affective mathematics learning outcomes.

The student' difficulties on solving mathematical critical thinking ability task were attached in Table 5.

Table 5
Mean Score of Each Item of Mathematical Critical Thinking Ability of Students in The Both Teaching Approach

Teaching approach	Stat. Desc.	No.1	No 2.	No.3	No.4	No.5
	Ideal score	20	20	20	15	25
SA	$\bar{X}$	12.77	12.23	8.49	9.17	7.83
	% of ideal score	63.86	61.14	42.43	61.14	31.31
	$\bar{X}$	11.57	9.77	7.06	6.71	5.69

Teaching approach	Stat. Desc.	No.1	No 2.	No.3	No.4	No.5
CT	Ideal score	20	20	20	15	25
	% of ideal score	57.86	48.86	35.29	44.76	22.74

Table 5 showed that students taught by scientific approach attained low score on item 3 and on item 5 (42.43, and 12.31 out of ideal score), and they were about to identify assumption of an inequality system problem, and to examine the truth of a statement. In others items students attained medium grades on mathematical critical thinking ability. Nevertheles, students taught by conventional still had difficulties on almost items of mathematical critical thinking ability.

Conclusion, Implication, and Suggestion

Conclusion

Based on findings and discussion, the study derives conclusion as follow.

The scientific approach took better role than expository teaching on improving students' mathematical critical thinking ability and its gain, and on students' mathematical dispossition. However the students' grades on mathematical critical thinking ability were still at low level and on mathematical disposition students' grades were at fairly good level. Most students in both teaching approaches realized difficulties in solving all mathematical critical thinking ability problems.

The other conclusion was that, there was high association between mathematical critical thinking ability and mathematical dipsosition and students performed positive perception toward scientific approach.

Suggestion

Based on the conclusion the study proposed some suggestion as follow.

The students' grade on mathematical critical thinking ability in both class were at low level. Mathematical critical thinking is classified as high order thinking (HOT) in mathematics. For obtaining HOT ability such as mathematical critical thinking abilty, students should master prerequisite of mathematical process and content of mathematical critical thinking ability firstly. So, before teacher are going to teach a new mathematics topic or content or to conduct study on other mathematical HOT ability, it is suggested to examine students' abilities of its prerequisite firstly. Besides that, students should be motivated to select and to solve more exercises by theirselfes on mathematical critical thinking ability or other mathematical HOT ability. In order students attained meaningfull mathematical critical thinking ability, it was suggested students to write the formulas and rules which used on each step in solving the problems as well.

To improve better students' mathematical disposition, it is suggested four ways as follow: Be aware of students to the importance of having mathematical disposition attitude; teacher should perform having behavior as wished in mathematical disposition; students should be accustomized having behavior as wished in mathematical disposition attitude; teacher should carry out integrated and continous mathematics teaching process.

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