Critical and Creative Mathematical Thinking of Junior High School Students

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ABSTRAK

Studi ini merupakan suatu eksperimen kuasi dengan disain kelas kontrol dan post-test serta memberikan pembelajaran dengan pendekatan eksplorasi dan bertujuan mengembangkan kemampuan berfikir kritis dan kreatif matematis siswa SMP. Subyek studi adalah 334 siswa kelas 8 dari tiga SMP level tinggi, menengah, dan rendah di Bandung. Instrumen studi adalah satu set tes berfikir kritis matematis dan satu set tes berfikir kreatif matematis. Data dianalisis dengan menggunakan 2 jalur ANOVA, MINITAB-14, dan Microsoft-Office-Excel 200. Studi menemukan bahwa: (1) Pendekatan eksplorasi lebih unggul dalam mengembangkan kemampuan berfikir kritis dan kreatif matematis siswa dibandingkan pembelajaran konvensional.; (2) Level sekolah, kemampuan awal matematika siswa merupakan predictor yang baik untuk pencapaian berfikir kritis dan kreatif matematis siswa. Namun demikian, pendekatan ekspolorasi lebih efektif untuk pencapaian berfikir kritis, sedangkan kemamapuan awal matematika berperan lebih besar dalam pencapaian berfikir kreatif matematis. (3) Terhadap pencapaian berfikir kritis dan kreatif matematis, tidak ada interaksi antara level sekolah dan pembelajaran, demikian pula tidak ada interaksi antara kemampuan awal matematika dan pembelajaran.

Kata Kunci: berfikir kritis, berfikir kreatif, kelancaran, kelenturan, originalitas, elaborasi, pendekatan eksplorasi

Critical and creative mathematical thinking skills are important and essential and should be attained by all mathematics students (KTSP, Hassoubah, 2004) The possesion of those mathematical abilities gave more opportunities for students to be flexible and open-minded, and in self adjustment to various situation and problems Moreover, Hassoubah (2004) stated that critical and creative thinking supported students'abilities on making desision, assessing and solving problems.

Bassically, each student, since his or her childhood tends to possess critical and creative thinking.. That tendency can be found on a situation when a young kid observes and tries every thing out curiously. In line with that tendency, Takwin (2006) proposed that development of critical and creative thinking should be fasilitated for students since early their childhood. Beside it was as a preparation for their next adulthood life, it also developed their human habit of open minded as well. But at present, students' abilities in critical and creative thinking were still low (Trianto, 2007). One of the reason was that students' learning was dominated by the teachers so that students could not reinvent mathematics concepts and they could not attain meaningful understanding as well. Students tended to memorize rules and algorithm of rutine problem, imitated teachers' explanation or examples of solving problem in a text book

Schoenfeld (Takwin, 2006) reported an example of students' work ilustrated that the students were not able to think critically as follow.

Suppose there are 26 sheeps and 10 goats in the field. What old was the breeder?

Students' answer were surprised. As many as 76 out of 97 students solved the problem by adding, subracting, multiplying, or dividing the integers 26 and 10. They thought that they should have to solve the problem quickly without try to understand the essence of the problem.

School curriculum or Kurikulum Tingkat Satuan Pendidikan (KTSP, 2005) in Indonesia proposed a change of teaching paradigm, from teacher centered to student centered, from expository to participatory, and from textual to contextual. The curriculum suggested that subject matter should be compiled from the simple concept or rutine process up to the more complex and should be accompanied by examples of the application, analysis, and syntesis of the concepts. To fulfill that suggestion, teacher should design their teaching approach more variative, innovative and should be constructivism oriented so they will motivate students' activities and creativity during students excuted an exploration.

In exploration approach students were motivated to reinvent a concept or to solve problem and they were fasilitated to make innovation in different ideas and ways. Teacher's role was to guide students to constrcut their knowledge actively by using a number of questions and tasks. Students were motivated to compile, to assess, to apply mathematics concept, to identify their chaterictics and relation among concepts and to compile logical conclusion. Those activities were related to the process of critical and creative thinking.

There are some related notion of critical thinking. Ennis (1985, in Baron, and Sternberg, (Eds) defines critical thinking as reflective thinking which leads to make a decision about what has been believed or done. Critical thinking related to five keys ideas those are: practicle, reflective, reasonable, belief, and action. Beside those five keys, critical thinking also had four main components those are: clarity, bases, inference, and interaction. Furthermore, Glaser (2000) defines critical mathematical thinking included ability and disposition which combined previous knowledge, mathematical reasoning, and cognitive strategy for generalyzing, prooving, assessing mathematical situation reflectively. Other writer, Langrehr (2003) stated that critical thinking is evaluative thinking included of employing relevant criteria in assessing information accompanied with their accuracy, relevancy, reliability, consistency, and their bias. Similar to Langrehr's statement, Bayer (Hassoubah, 2004) proposes that critical thinking included abilities of determining credibility of a source, differenciating between relevant and irrelevant things or facts, identifying and analyzing assumption, identifying bias and view, and assessing proof.

Some writers defined creativity in different ways, but those definition included similar component as like aspect of newness (Alvino in Cotton, 1991, Coleman and Hammen, in Yudha, 2004, Marzano in Hassoubah, 2004, Musbikin, 2006, Papu, 2001, Yudha, 2004). Alvino (Cotton, 1991) posed that creative thinking included four components: fluency, flexibility, originality, and elaboration. Papu (2001) claimed creativity included four processes namely: exploring, inventing, choosing, and implementing; and Yudha (2004) stated five steps of creative thinking those are: orientation of problem: formulate problem, and identify component of the problem; preparation: collecting relevant information to the problem, incubation: taking a rest for a moment, when problem solving process was stag, ilumination: looking for ideas and insight for solving problem; and verification: testing and assessing the solution critically.

Coleman and Hammen (Yudha, 2004) claimed that creative thinking was a way of thinking which produce a new concept, finding, or art creation.. Sukmadinata (2004) proposed similar opinion that creative thinking is mental activity included originality, sharp insight, and generating process. Some steps in creative thinking were: posing question, considering information in a new view and open minded, looking for relationship among different things, seeing free relationship between one and others, applying his thought to produce new and different things, and considering intuation.

In line with that opinion, Marzano (Hassoubah, 2004) suggested that to become a creative thinker, we should have: 1) Work at the end of our competency with high confidence and feel challenged; 2) Reconsider our ideas from the other point of view; 3) Do something by internal and not external motive; 4) Have divergent thinking, 5) Have a lateral thinking or imaginative thinking, and vertical thinking.

Balka (Mann, 2005) proposed that creative mathematical thinking included convergent and divergent thinking abilities that could be detailed as follow: 1) ability to formulate mathematical hypotheses which focussed on cause and effect of mathematical situation, 2) ability to determine mathematical pattern, 3) ability to break a deadlock of thinking by posing new solutions of mathematical problem, 4) ability to pose unsual mathematical

ideas and to assess their conseqences, 5) ability to identify the lost information of the problem, 6) ability to detail general problem into more specific sub-problems. Musbikin (2006) defined creativity as an ability in compiling ideas, seeing new relationship or unpredictable, formulating unmemorized concept, creating new answer from original problem, and posing new question.

Related to teaching approach, Meissner (2006) suggested that to improve students' creative mathematical thinking ability the teacher should pay attention on individual and sosial development, preparing challenging problems, encouraging students to pose more spontaneous ideas, and posing more reasoning problems. In line with Alvino, Zizhao and Kiesswetter (Meissner, 2006) identified the chatheristic of creative person they were: be self confident or self regulated, have relative originality, and have flexibility thinking. Likewise, Nicholl (2006) suggested some steps to become a creative person. Those were: collect information as much as possible, think from four directions, pose many ideas, look for the best combination of ideas, decide which was the best combination, and realize the action.

Other studies such as Innabi (2003) studied teaching activities of 38 yunior mathematics teacher in Amman Yordan. Those activities were recorded and the teachers also noted their activities themselves. Based on the analyses on the Ennis' components of critical thinking, the study found that only 40.7 % teacher activities was classfied as creative activities. Moreover 80 % out of 40.7 % of those activities included general creative activities as ability and disposition, and only 20 % activities were classified as creative mathematical process Innabi identified the reason of teachers not oriented their teaching to the ciritical thinking development of their students, some of them were: 10 teachers did not view that critical thinking was part of the main objectives of their teaching, 2) teachers had limited knowlege of characteristic of critical thinking and strategies for improving that students' abilities, 3) teachers were bound on national curriculum.

Some others studies (Fahinu, 2007, Ratnaningsih, 2007, Rohayati, 2005, Syukur, 2005) reported that although in general the students' critical ability were classified as medium, the innovative teaching that fasilitated students to think tended to improve students' critical thinking ability better than that of conventional teaching. Similar to that findings, Syukur (2005) by using open ended approach with senior high students, Rohayati (2005) by using contextual teaching with yunior high students, Fahinu (2007) by using generative approach with under graduate students and Ratnaningsih (2007) by using contextual approach with senior high students, reported that students taught by using the innovative approaches attained better grades on critical mathematical thinking ability than that of students of conventional classes

Other studies (Mann, 2005, Mira, 2006, Pomalato, 2005, Ratnaningsih , 2007, Shihu and Jijian, 2001) reported similar findings on creative mathematical thinking ability. Shihu and Jijian (2001) by experimenting exploration approach with yunior high students found that students of exploration approach and conventional approach attained almost same grade on some aspects of divergent thinking ability. But related to affective aspect, students of the exploration approach tended to show better on interest and atractiveness to learning mathematics than that of students of conventional approach. Different with Shihu and Jijian's finding, Mann's survey (2005) with 89 yunior high students by using Creative Ability in Mathematics Test (CAMT), Connecticut Mastery Test (CMT), Fennena-Sherman Mathematics Attitude Scales, and Scales for Rating Behavioral Charateristics of Superior Students reported that there was a correlation between mathematics ability and creativity ability, and between students' perception and attitude. More over female students attained better grade than male students on creativity. Likewise, Pomalato (2005) by implementing Treffingger Model with junior high students and Mira (2006) by using Open-Ended approach with senior high students reported that the studens of experiment class performed better in creative mathematical thinking than the students of conventional class. Furthermore, Ratnaningsih (2007) by experimenting contextual approach accompanied with unstructured problem and with structured problems reported that students of the first approach attained better grade than that of the second approach on creative mathematical ability, and both of them were better than students of conventional approach on creative mathematical ability as well. In general students' creative mathematical ability were classified as fairly good.

The analysis of teaching approaches, findings, opinion and sugestion of the writers and reseachers above and the mathematics features encouraged

researchers to conduct a quasi experiment to analyze the influence of exploration approach, students' previous mathematics ability, and school level on students' critical and creative mathematical thinking ablities.

Method

This study was a quasi experiment with posttest control group design by using exploration approach conducted to investigae students' critical and creative mathematical thinking ablities. The subject of this study were 234 grade-8 students form six selected classes of three yunior high schools with different clusters (low, medium, and high). Teaching material was compiled to fit to the exploration approach. The experiment involved three kinds of instruments: previous mathematics ability test, critical mathematical thinking test, and creative mathematical thinking test. The creative mathematical thinking test consisted four components: fluency, flexibility, originality, and elaboration. The data was analyzed by using software MINITAB-14 and Microsoft-Office-Excel 2007.

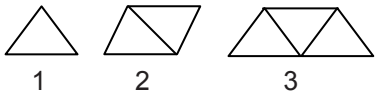
In the following, we presented two examples of critical mathematical thinking test and of creative mathematical thinking test.

Example 1: Assessing critical mathematical thinking ability

> Thirty five students of grade 5 of Harapan Elementary School visit a books exhibition. There is a great sale for 50 story books which consist 12 adult story books and the rest are children story books. The students are interested to buy some children story books For buying 5 children story books the students pay Rp 37.500,00. If the students buy all children story books they only pay Rp. 190.000,00. Which one of the two offers that give bigger profit to the students? Explain your reason.

Example 2: Assessing creative mathematical thinking ability

The picture bellow is compiled by matchstick.



Pattern 1 2 3 and soon

Based on the pattern above, count how many matchsticks in pattern-100. How do you get your answer? Then construct another picture with different pattern.

Determine the form of your new pattern and count how many matchsticks in pattern-4. Explain how you get your answer.

Pattern 1 2 ? 4

Findings and Discussion

1. Previous mathematics ability

Before experiment cunducted, the students were clasified into three groups based on their scores of prior mathematics ability. The test was an essay and included prerequisite concepts of the topics that will be taught in this study. The study found that: 1) The higher the school cluster the higher the students' mathematics ability. as well. 2) There was no difference on prior mathematics ability among students' in all classes, and it was classified as fairly good so the researchers decided to carry out the experiment directly.

2. Critical mathematical thinking ability

Students' critical mathematical thinking ability was described in detail in Table 1.

The data on Tabel 1 pointed out that exploration approach was more effective for improving critical mathematical thinking ability than that of conventional approach. Students taught by using exploration approach attained higher on critical mathematical thinking ability than that of students of conventional class and both of them were classified as fairly good. In a depth analysis on exploration and conventional classes it was found that the higher the school cluster and students' prior mathematics ability the higher the students' critical mathematical thinking ability as well. Those findings showed that school cluster and previous mathematics ability had similar role as good predictors for attaining critical mathematical thinking ability. The result of testing the roles of school cluster, previous mathematics ability, and teaching approach to the attainment of critical mathematical thinking ability were presented in Tabel 2 and Tabel 3. There was no interaction between school cluster and teaching approach to the attainment of critical mathematical thinking. Likewise, there was no interaction between previous mathematics ability and teaching approach to the attainment of critical mathematical thinking as well.

Table 1: Students' critical mathematical thinking ability based on School clusters, previous math ability (PMA), and teaching approaches

School cluster	Previous math ability (PMA)	Teaching approach			
		Exploration		Conventional	
		Mean	Number of ss	Mean	Number of ss
High	High	36.53	17	32.1	16
	Medium	31.75	24	27.2	23
	Low	24	1	22	1
Sub Total		33.5	42	29.03	40
Medium	High	33.8	5	33.67	3
	Medium	29.9	30	28.52	29
	Low	25	5	25.4	5
Sub Total		29.80	40	28.51	37
Low	High	30	3	33	3
	Medium	27.48	21	26	20
	Low	22. 7	15	24	13
Sub Total		25.90	39	26.06	36
Total		29.83	121	27.91	113

Note: Ideal score is 50

Table 2: Anova two path of school cluster and teaching approach on critical mathematical thinking ability

Source	JK	Dk	RJK	F	F tab
School cluster (A)	1127.58	2	563.79	25.76	3.08
Teaching approach. (B)	214.27	1	214.27	9.79	
AxB	221.87	2	110,93	5.07	
Inter	5034.60	230	21.89		

Table 3: Anova two path of previous mathematics ability and teaching approach on critical mathematical thinking ability

Source	JK	dk	RJK	F_{hit}	F_{krit}
School cluster (A)	2239,12	2	1119,56	62,80	3.08
Teaching approach. (B)	212,29	1	212,29	11,91	
AxB	86,03	2	43,01	2,41	
Inter	4064,55	228	17,83		

Creative mathematical thinking ability

Students' mathematical creative thinking ability was presented in Table 4. The findings similar to mathematical critical thinking were also obtained on creative mathematical thinking as well. The exploration approach was able attained better on mathematical critical thinking ability than that of students of conventional class It was also found that mathematical creative thinking more difficult than mathematical critical thinking. It was in line with finding of assosiation between mathematical critical and mathematical creative thinkng in Table 5.

There was no student who attained high creative mathematical thinking, most of the students with medium critical thinking were classified as low creative thinking, more over almost of the students with low critical thinking attained low creative thinking as well. Those findings were in line with the believe that for obtaining creative

mathematical thinking students should understand mathematics concept and critical thinking. Some students' difficulties on solving critical task were inaccurateness in identifying data, solving problem with multiple variables, formulating mathematical representation, assessing problem solving process, and unable to make connecting among concepts. Whereas students' difficulties on mathematical creative thinking were posing problem based on given situation, unabled to reason mathematically, solving problem in many ways, and making connection between their new ideas and their previous mathematical concepts.

Conclusion

Based on the findings and discussion, the study concluded that the school clusters tended to be a bigger role than prior mathematical ability on obtainning the critical and creative mathematical thinking. However, the exploration approach performed the best role for attaining critical and creative mathematical thinking compare to the roles of conventional approach, school clusters and student prior mathematical ability. There was no interaction between teaching approach and school level and between teaching approach and previous mathematical ability on attaining the critical and creative mathematical thinking as well. Moreover, creative mathematical thinking tended more difficult than critical mathematical thinking for yunior high school students, and some them still posed dificulties in both thinking abilities.

The other conclusion was that during the exploration approach students performed more self confident in presenting their different ideas among their friends. Almost of students participated on

Table 4: Creative mathematical thinking, teaching approach, school level, and previous mathematics ability

School cluster	Previous math ability (PMA)	Teaching approach			
		Exploration		Conventional	
		Mean	Number of ss	Mean	Number of ss
High	High	36,2	17	32,94	16
	Medium	29	24	25,91	23
	Low	24	1	21	1
Sub Total		31,81	42	28,60	40
Medium	High	35,2	5	29,67	3
	Medium	28,53	30	26,59	29
	Low	24	5	24,6	5
Sub Total		28,80	40	26,57	37
Low	High	31	3	31,33	3
	Medium	27,7	21	25,7	20
	Low	22,6	15	23	13
Sub Total		26	39	25,19	36
Total		28,94	121	26,85	113

Note: Ideal score is 60

Table 5: Assosiation between critical and creative mathematical thinking

Critical thinking	Creative thinking			Total
	Low	Medium	High	
Low	130	4	0	134
Medium	76	19	0	95
High	1	4	0	5
Total	207	27	0	234

Table 6: Two ways anova on creative mathematical thinking, teachng approach, and school cluster

Source	JK	Dk	RJK	F	F tab
School cluster (A)	844,72	2	422,36	15,67	3.08
Teaching approach. (B)	255,87	1	255,87	9,49	
AxB	56,75	2	28,38	1,05	
Inter	6147,20	228	26,96		

Table 7: Two ways anova on creative mathematical thinking, teachng approach, and previous mathematics ability

Source	JK	dk	RJK	F_{hit}	F_{krit}
School cluster (A)	2665,39	2	1332,70	70,16	3.08
Teaching approach. (B)	255,87	1	255,87	13,47	
AxB	72,65	2	36,32	1,91	
Inter	4330,94	228	19,00		

class communication, whereas in conventional class communication was dominated by the smarter students only.

Implication and suggestion

Among teaching, students, and school level variables, the biggest role for improving critical and creative mathematical thinking was the exploration approach. Implication of that statement was that exploration approach was a good alternative teaching approach to develop critical and creative mathematical thinking ability and may be for others high order mathematical thinking abilities.

Some suggestion for implementing exploration approach among others are: 1) teachers should be creative and accurate in preparing mathematical questions and tasks that motivate students to explore some ideas and to solve problem in different ways; 2) Formulate questions and tasks that fit to students' development and sellect ilustration so that invite students' interest, 3) teachers' help should be minimized and don't in a hurry so that students' potential growth develops optimally; 4) consider the length of time and sellect the essential mathematics topics; 5) develop students' reinforcement of prerequisite concepts, for example by using probing and scaffolding techniques.

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