Available online at http://journal.uny.ac.id/index.php/jrpm

Jurnal Riset Pendidikan Matematika 10 (2), 2023, 128-138

Students' mathematical critical thinking through the conceptual change approach

Fitria Maghfiroh *, Dadan Dasari

Department of Mathematics Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
E-mail: marten.fitria@gmail.com
* Corresponding Author

ARTICLE INFO

Article history
Received: 19 Jun 2023
Revised: 18 Oct 2023
Accepted: 30 Nov 2023

Keywords
conceptual change approach, critical thinking, junior high school mathematics, quasi experiment

Scan me:

ABSTRACT

Critical thinking ability is one of the higher order thinking skills. Students who have high critical thinking skills are expected to have the ability to analyze problems properly and precisely. The purpose of the present study was to find out the differences in students' mathematical critical thinking skills who received learning using the conceptual change approach and those who received conventional learning, namely the scientific approach. This study was conducted at a junior high school in South Tangerang City, Banten Province. The research method used was a quasi-experimental research design with a post test only control design. The research sample consisted of 70 students consisting of 37 students in the experiment group and 33 students in the control group selected by a cluster random sampling technique. Results indicate that students' mathematical critical thinking skills who learned with the conceptual change approach are higher than those of students who learned by the scientific approach. The critical thinking skills of students who received learning by the conceptual change approach were 72.64%, on the indicator of analyzing arguments, 67.23%, on the indicator of making conclusions, 84.46%, on evaluating, and 61.85% on solving problems.

How to Cite: Maghfiroh, F., Dasari, D. (2023). Students' mathematical critical thinking through conceptual change approach. *Jurnal Riset Pendidikan Matematika*, 10(2), 128-138, http://dx.doi.org/10.21831/jrpm.v10i2.62812 .

INTRODUCTION

The purpose of learning mathematics is to train students' thinking skills such as in a systematic and deductive way of thinking like what is contained in the Decree of the Minister of Education and Culture (Permendikbud) No. 22 Year 2016 (BNSP, 2016). Seeing this goal, students' thinking skills in Indonesia should have a fairly high average, but, contrary to the facts, students' thinking skill in Indonesia is low (OECD, 2019). Most students in Indonesia still experience difficulties in solving mathematical problems, such as in analyzing existing arguments to find the information needed to solve problems, determining strategies to use, drawing conclusions, and evaluating the results of their work. Some students also still have difficulty in connecting the knowledge they have acquired with new knowledge. Students also tend to memorize formulas in place of understanding the concept of how a formula is obtained and used (Hidayatullah *et al*., 2021 p. 628). For a student, as a matter of fact, having good thinking skills is very important because students who have good thinking skills tend to be more confident in their learning process.

One of the thinking skills needed in the 21st century is the critical thinking skill. Based on the National Education Association (NEA), critical thinking is part of the four most important specific skills known as the Four Cs, namely critical thinking, communication, collaboration, and creativity. Critical thinking is one of the most important life skills for students because by having it they will be more proficient in solving problems, both simple and complex (Setiana & Purwoko, 2020, p. 2). Besides, students' rational reasoning can be developed so that they can make good decisions based on their beliefs

(Farib *et al*., 2019, p. 100). In addition, critical thinking makes students more sensitive to their surroundings so that they are able to sort out information they need (Khoirunnisa & Malasari, 2021, p. 50). Most schools in Indonesia have participated in developing critical thinking skills by applying a scientific learning approach under the provisions of the 2013 Curriculum which is oriented towards improving higher-order thinking skills; but, in practice, there are still many other intervening factors that make learning objectives be not optimally achieved such as the use of models, strategies, or learning approaches that are not appropriate and the lack of practice questions that lead to students' mathematical critical thinking skills.

The use of appropriate learning models or approaches will direct students to systematically analyze, synthesize, evaluate, and solve problems. These activities are essential in training critical thinking skills. Students who have high critical thinking skills will be able to express their ideas and provide evidence and also reasons for what they believe in (Tittle, 2011, p. 9). For example, when faced with a problem, students who have good critical thinking skills will remain confident if the answers they find are different from those of other students'. This is because they can provide evidence and reasons for how they obtain the answer. In terms of solving problems, students who have good critical thinking skills will be able to analyze and evaluate problems from various points of views (NEA, 2011, p. 9). They can relate the knowledge they have acquired with new knowledge to solve the problems they face. Critical thinking skills will help students develop other mathematical skills (Rohmah & Z Mashuri, 2021, p. 64). Therefore, applying the right learning approach is very important in improving students' critical thinking skills.

One of the learning approaches applied in the present study is that which is called the conceptual change approach (CCA). Learning with CCA is one that comes from constructivism. The thing that is really needed in learning that adheres to approach is the notion of the very significant role of the teacher as a facilitator, a guide, not one who provides teaching (Ozkan & Selcuk, 2012, p. 183). Learning that uses conceptual change will provide opportunities for students to understand the concepts found by the experts as a whole and complemented by contextual examples and applications (Wilujeng & Hidayatullah, 2021, p. 112). This means that students can provide explanations and use derivatives of the concepts they own to solve relevant problems. According to Posner *et al*. (1982), there are four critical conditions for the conceptual change approach to be applicable: 1) Students' awareness of the discrepancy between the previous concepts and the current ones (dissatisfaction); 2) the new concept must be understood (intelligibility); 3) the new concept must be acceptable (plausibility) which means that students are able to use it and it can be easily described in their frame of mind; and 4) the new concept must be fruitful for students (fruitfulness) in that students can use it to solve relevant problems. In addition, there are four stages in the conceptual change approach according to Nussbaum & Novick (1982). In the first stage, students will be asked to explain the initial concepts they receive either from the teacher or from their experiences, in which case they will explore their knowledge based on the initial concepts they get. This will make students analyze the arguments related to the initial concept and then make conclusions about the initial concept that they understand. In the second stage, the teacher gives a conceptual conflict based on the students' initial concept so that they will return to analyzing new arguments, evaluating the initial concepts and new concepts given by the teacher, and then making conclusions based on their observations of the two concepts presented. In the third stage, students carry out discussion and evaluation activities to strengthen the conclusions they have made in solving the problems presented. In this case, students return to analyzing arguments, solving problems, and evaluating the problem-solving that has been done. In the fourth stage, students carry out a concept reconstruction of the initial concepts they acquired to produce new concepts that are following the new problems they get. This will make students return to analyzing arguments, drawing conclusions, solving problems, and evaluating.

Based on the description of the stages in learning using the CCA, it appears that this approach has a close relationship with the indicators of critical thinking put forward by Lai (2011). These are 1) analyzing arguments: identifying intended and actual inferential relationships among statements, questions, concepts, or other forms of representation intended to express beliefs, judgements, experiences, reasons, information, or opinions; 2) solving problems: applying the concepts that have been learned to decide on alternative solutions or appropriate actions for the given problems; 3) evaluation: assessing the credibility of statements or other representations that are calculated or described from a person's perceptions, experiences, situations, judgments, beliefs, or opinions; and to

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

assess the logical strength of actual or intended inferential relationships among statements, descriptions, questions, or other forms of representation; and 4) Making conclusions: assessing the reasons for whether or not something is acceptable so that one can know the truth in drawing conclusions and making inductions and consider the results of the induction. Based on these linkages, this approach has a very high possibility of improving students' critical thinking skills. In this relation, the present study is aimed at seeing the improvement of students' critical thinking skills taught by using the conceptual change approach compared to that of students' mathematical critical thinking skills taught by using a conventional learning approach and finding an alternative approach to enhance students' critical thinking skills. The distinction of this study from the previous one lies in the indicators of critical thinking according to what is stated by Emily Lai, which are are analyzing arguments, making inferences, evaluation, and solving problems, while the stages of the conceptual change approach used are derived from the study by Nussbaum and Novick which are revealing students' initial concepts, giving conceptual conflicts, discussion and evaluation, and concept reconstruction.

METHOD

The study used the quasi-experimental research method with a posttest-only design to examine the students' mathematical critical thinking after the treatment was applied. This method was used because the experiment was held at the school where the researcher could not possibly have intensive control on all the research variables involved, Meanwhile, the posttest-only design was used because the study was going to measure the students' critical thinking which was one of the higher order thinking skill criteria in which the questions or test items were given only at the end of the experiment whereby the testees had never seen before.

Population and sample

The population of the study pointed at all the students of class VIII at one of the State Junior High Schools (SMPN) in South Tangerang City, Banten Province. The research sample consisted of 70 students who were randomly selected using the cluster random sampling technique. Furthermore, the selected sample was divided into two groups: 37 students were placed in the experimental group and 33 in the control group. The learning treatment used in the experimental group was the conceptual change approach while that in the control group was the scientific approach. The scheme of this study is illustrated in Table 1.

Table 1. Research Design

Group	Treatment	Posttest
Control	X	O_1
Experiment		O_2

(Setyosari, 2017, p. 212).

Research data

The data to be analysed in the study came from the results of the tests administered to the two sample groups at the end of the treatment. The instrument was in the form of a descriptive essay-type test given as a posttest to measure the students' mathematical critical thinking skills. There were eight questions which consisted of four indicators of critical thinking skills; namely the ability to analyze arguments, solve problems, evaluate, and make conclusions. The results of the calculation of the critical thinking scores were interpreted as the levels of the critical thinking categories as shown in Table 2.

Data analysis

Before the test instrument was administered, it was subjected to a product-moment correlation analysis to appraise the validity and reliability measures of the test and make sure that the test instrument had a high level of confidence and gave consistent results. Furthermore, the data analysis concernimg the research hypothesis-testing used the Mann-Whitney statistical test with a confidence level of 5% on the SPSS computer software after previously carrying out normality and homogeneity tests on the data.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

Table 2. Levels of Critical Thinking

Percentages	Critical Thinking Categories
$80 < x \leq 100$	Very good
$60 < x \leq 80$	Good
$40 < x \leq 60$	Moderate
$20 < x \leq 40$	Less
$0 \leq x \leq 20$	Very less

x = Students' score (Arikunto, 2010)

RESULTS AND DISCUSSION

The data analyzed came from the results of the posttest which consisted of eight essay test questions in the forms of mathematical critical thinking indicators. The test was administered to the experimental class and the control class with equal conditions and time alottment of ninety minutes. The recapitulation of the results of the post test is presented in Table 3 which consists of the average score, standard deviation, normality test results, homogeneity, and also the results of the hypothesis test.

Table 3. Students' Critical Thinking Test Results

Learning Approach	*N*	Mean	Standard Deviation	Normality (Shapiro-Wilk)	Homogenity	*t*-test
CCA	37	71.54	13.913	0.010	0.254	0.004
SA	33	63.61	11.916	0.033		

CCA: Conceptual Change Approach
SA: Scientific Approach

Table 3 shows that the mean of experiment group is higher than that of control group. This can be interpreted that students in experiment group have higher critical thinking skills. The results of the analysis of both data come from populations that are not normally distributed because the values of the normality statistics of both groups are smaller than the specified significance level of ($\alpha = 0.05$). This happens because there are some values that are too extreme (outliers) in both data so that the range between the highest and lowest values is very far which influences the data distribution skewness, whether skewed to the right or to the left. However, even though the data obtained are not normally distributed, the results of the homogeneity test in both classes show that both samples come from homogeneous data, which means that the variance distribution of the two data is the same. These two conditions make it possible the carrying-out of the nonparametric type statistical test for the hypothesis testing procedures.

After the normality and homogeneity tests were conducted to see whether there were differences that occurred in the two classes in receiving the different research treatments, the Mann-Whitney non-parametric test for the hypothesis-testing was carried out. The results of the hypothesis testing show that the significance value of the data in the post-test is 0.004. Because this study uses a two-tailed test, the results of the test are found to be smaller than the predetermined significance level of ($\alpha = 0.05$). This means that there is a significant difference in the influences between the mathematical critical thinking skills of students who receive learning by the conceptual change approach and those of students who receive learning by the scientific approach. The critical thinking of students who are taught by the conceptual change approach is significantly higher than that of students who are taught by the scientific approach.

Students' critical thinking level

Based on the scores of critical thinking tests obtained in the post test, the data can be levelled into some categories of critical thinking skills. These data sre the union from both the experiment and control groups (Table 4). From this table, it can be seen that most of students are in the moderate level for acquiring mathematical critical thinking. However, no student is found in the "very low" level. This indicates that each approach applied in each group has the possibility of developing students' critical thinking; this is because each approach comes from the constructivism learning theory. To see the detail

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

about which approach affects more in improving students' critical thinking, the data should be compared based on the approach and the indicators used.

Table 4. Students' critical thinking level

Critical thinking category	Number of students	Percentage
Very good	14	20%
Good	17	24%
Moderate	32	46%
Low	7	10%
Very low	0	0%

Comparison of students' critical thinking in each indicator

The results of the hypothesis testing which states that there are significant influences of conceptual changes on students' critical thinking skills between the experimental group and the control group can be seen more clearly. This can be done by comparing the two sets of data as it is shown in Table 5.

Table 5. Students' critical thinking scores

Mathematical Critical Thinking Indicators	Total Score	Experiment		Control	
		Mean	%	Mean	%
Analyzing argumenta	8	5.81	72.64	5.73	71.59
Making conclusions	8	5.38	67.23	4.61	57.58
Evaluation	8	6.76	84.46	5.82	72.73
Solving problems	8	4.95	61.85	4.18	52.27

The table above shows that the percentages of students' mathematical critical thinking skills in the experiment class are higher than those of the control class. Students who are taught by the conceptual change approach are used to applying the scientific method in finding new concepts or examining the initial concepts to understand the lesson. This process encourages the students to maximize their reasoning skills, especially critical thinking. According to Putra (2014), this condition also happens in his study where the conceptual change approach bridges students' understanding of scientific concepts. Two question items in the post test measure students' mathematical critical thinking skills on the indicator of analyzing arguments. Most of the students in both the experiment group and the control group are able to answer the questions correctly, but the experiment class provides their answers accompanied by the application of a concept and the reasons for underlying the answers they give such that their answers are more perfect than those given by students in the control group. They are able to state the reasons why the answers should be given by their own language and highlight the keywords to support their answers. This is because students in the experiment group are used to conditions where they are required to give reasons for solving problems and the concepts they use which lead to their critical thinking improvement (Rizaldi *et al*., 2019, p. 79). The perfection of the answers given by students in the experimental class is due to the learning model which applyies Ausubel's learning theory, a meaningful learning where learning will occur if students can relate new concepts with initial ones to discover new knowledge (Gazali, 2016, p. 185).

The perfection of the answers given by the experiment group students also manifest the results of the study conducted by Syuhendri (2017) in which it is stated that the conceptual understanding of students who are given the conceptual change model is superior compared to that of students given other learning models. In this case, in the present study, students' understanding of the arguments given in the question items is better. Figure 1 and figure 2 present examples of the answers given by students of the control and experiment group in answering questions on the indicator of analyzing arguments.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

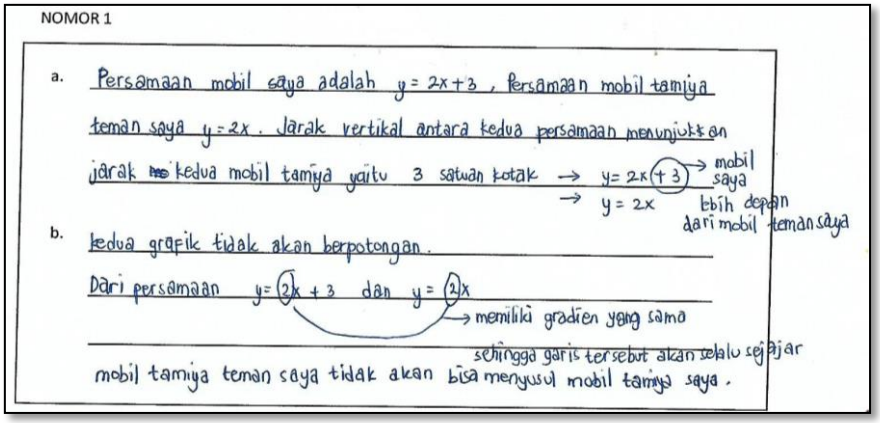

Figure 1. Student's answer in the experiment group on the indicator of analyzing arguments

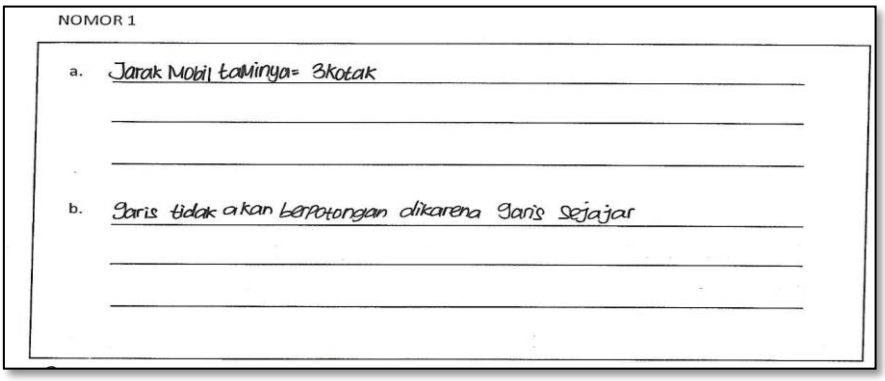

Figure 2. Student's answer in control group on the indicator of analyzing arguments

On the indicator of making conclusions, the ability measured is the accuracy of students' answers in assessing whether something can be accepted or rejected, deciding actions and making inductions, and considering the results of the inductions that have been carried out. In the experiment group, most of the students make three alternatives to answer the given problem (Figure 3), while in the control group, most of the students only provide one alternative to answer the problem (Figure 4). Differences in interpreting the problems and providing several alternative answers carried out by the experiment group students are influenced by the process of adaptation to problems they have received on similar questions. This is because the experiment group students can carry out the process of equilibrium, where the processes of assimilation and accommodation are balanced, coming from the application of the conceptual change learning approach. The conceptual change approach applies the learning theory expressed by Piaget of the adaptation of prior knowledge with new knowledge which consists of assimilation and accommodation processes. Assimilation is a cognitive process where students will collaborate their insight with the scheme or pattern they have in their mind according to their experiences to gain the new knowledge (Juwantara, 2019, p. 29). Accommodation is the process where students collect information to create a higher specific cognitive system with better functions (Nuryati & Darsinah, 2021, p. 156). This process encourages students to do their own observations and reasoning by applying the initial concepts and then making adjustments in the application to solve the new problems they face (Pebriyanti *et al*., 2017, p. 92). The following is an example of a student's answers on the indicator of making conclusions.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

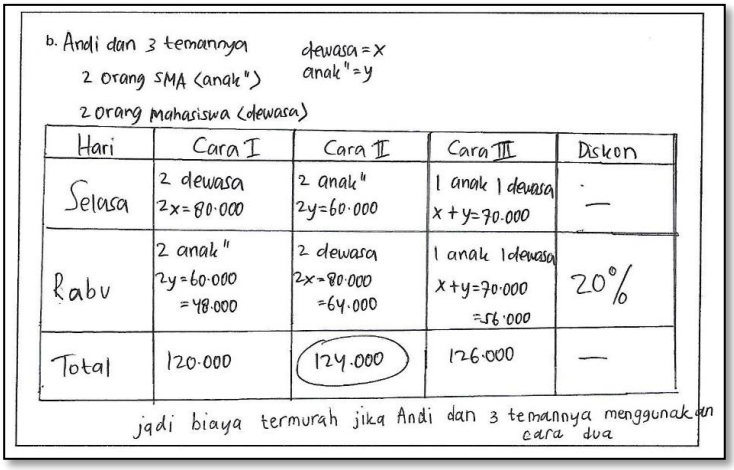

Figure 3. Student's answer in the experiment group on the indicator of making conclusion

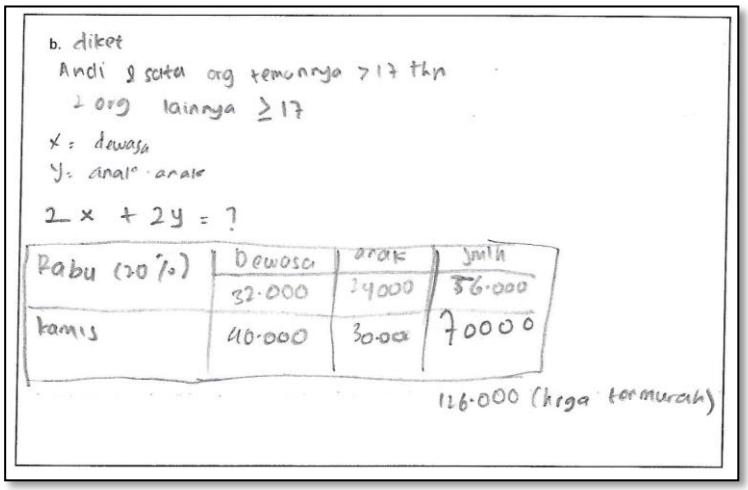

Figure 4. Student's answer in the control group on the indicator of making conclusion

The ability measured on the evaluation indicator includes identifying problems, performing calculations, and assessing the intended logical strength of questions. Students in both the experiment group and control group are mostly able to solve questions this evaluating indicator. This indicator obtains the highest score among the others. This is an interesting result. Looked more deeply at the two treatment approaches, both approaches are derived from the constructivism theory where students in the two groups are encouraged to participate more actively as expected by both approaches. According to Vygotskyan theory, the role of students' social interaction such as the interaction of a student with his peer or with his teacher is meant to help students in the zone of proximal development to solve problems (Azizah & Purwaningrum, 2021, p. 22). This condition exists in the two approaches used. There is a stage of learning in the conceptual change where students are asked to discuss and evaluate the problems they have which leads to the process of equilibrium to reach new understanding. Likewise, in the scientific approach, there is also the stage where students have the chance to explore their understanding through asking questions, reasoning, and communicating (Yanwar & Fadila, 2019, p. 11). This is the reason why students in both the control group and the experimental group are mostly able to identify questions well and perform calculations correctly. They are facilitated in solving a problem correctly and showing good evaluation skills. This condition is in line with the results of the study conducted by Rachmawati & Supardi (2021) which show that the conceptual change approach can reduce students' misconceptions and can make them better in evaluating abilities. Figure 5 and figure 6 show examples of students' answers on the indicator of evaluation.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

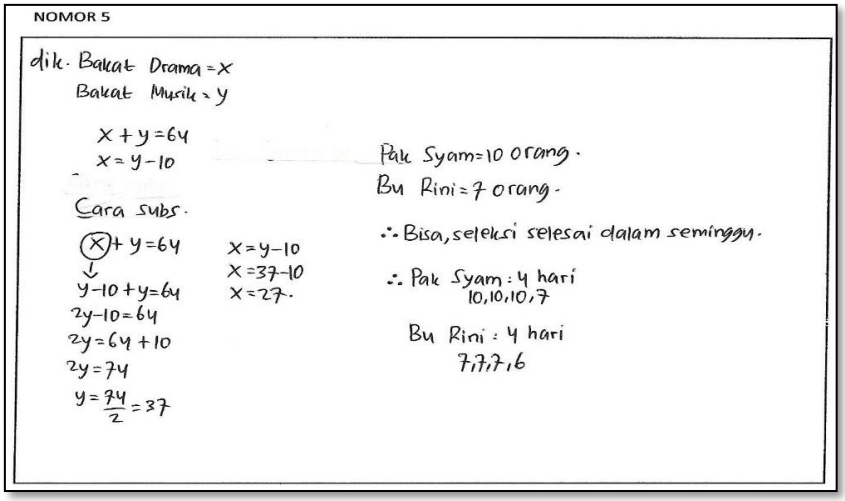

Figure 5. Student's answer in the experiment group on the indicator of evaluation

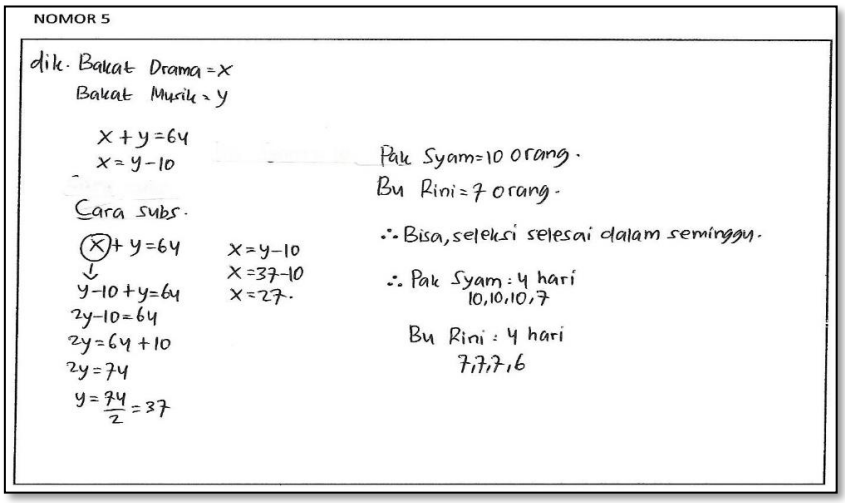

Figure 6. Student's answer in the control group on the indicator of evaluation

On the problem-solving indicator, the critical thinking skills that are measured consist of the ability to identify problems and apply the right concepts to find solutions. The highest percentage in this matter is shown by the experiment group. Students in experiment group are able to give three types of solution, which is a good thing because they can show their analysis more deeply through some possible conditions they can see from the description of the question. Meanwhile, in the control group, they can only provide one alternative solution. In this case, the number of alternative solutions will show the initiative and how students' critical thinking is developed. The success of problem solving is related to how students' daily learning is conducted (Widayati, A.D., Triyanto, Pambudi, 2019, p. 397); therefore, students in the experiment group can have this initiative. This happens because the experiment group is familiar with the learning process where one of the stages is giving conceptual conflicts, which requires students to explore the concepts that have been obtained to get an appropriate solution in solving problems, as based on Piaget, Ausubel, and Gagne's learning theories. In Gagne's learning theory, learning outcomes can be shown as cognitive strategic abilities where students can demonstrate the complexity of their knowledge in new situations facilitated by the teacher as a guide to solving a problem (Dahar, 2011, p. 95). In applying the conceptual change learning approach, the teacher guides students to find their knowledge by providing a conceptual conflict so that this can train students to get used to do equilibrium in solving a problem. Equilibrium is a balancing process in which students try to understand new knowledge by adapting from their mind from previous stage of thinking to the next stage (Rohaendi & Laelasari, 2020, p. 68). In this equilibrium process, students will explore more so that they can identify problems correctly, apply the right concepts to solve problems, and then decide

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

on the right solution to a problem. Figure 7 and Figure 8 are examples of students' answers on the indicator of solving problems.

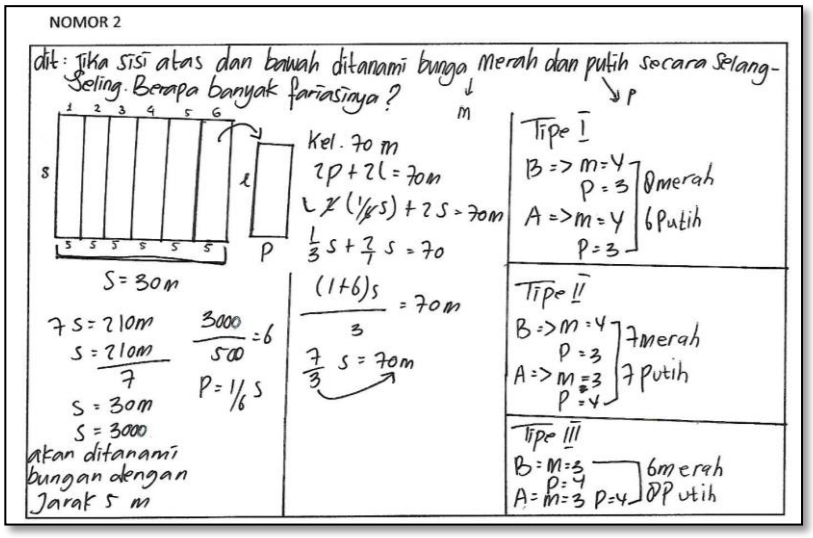

Figure 7. Student's answer in the experiment group with the indicator of problem solving

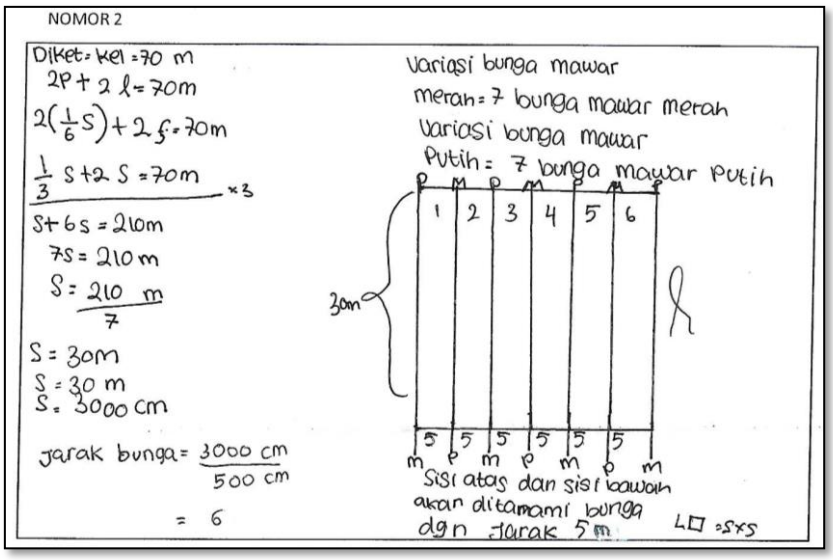

Figure 8. Student's answer in the control group on the indicator of problem solving

CONCLUSION

The results of the present study show that the conceptual change approach of learning can enhance students' mathematical critical thinking. This is supported by the descriptive and inferential analysis results which show a significant difference in students' critical thinking in that students whose learning uses the conceptual change approach have higher scores than those of the control group whose learning uses the scientific approach. This indicates that students' critical thinking through the conceptual change approach is significantly improved.

Based on this finding, it is suggested that the conceptual change approach to learning be used as an alternative in the class instructional interaction to develop students' critical thinking. For the teachers, especially who are willing to apply this approach in their learning process, it is suggested that they be more concerned in the step of discussion and concept reconstruction, because it takes the most of the time from the whole learning.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

REFERENCES

Arikunto, S. (2010). *Prosedur penelitian: suatu pendekatan praktik* [Research procedure: a practice approach] (14th ed.). Rineka Cipta.

Azizah, I. N., & Purwaningrum, J. P. (2021). Penerapan teori vygotsky pada pembelajaran matematika materi geometri [Application of Vygotskyan theory in mathematics learning on the geometrical material]. *Jurnal Riset Pembelajaran Matematika* [Mathematics Learning Research Journal], *3*(1), 19–26. https://doi.org/10.55719/jrpm.v3i1.220

BNSP. (2016). Permendiknas RI no. 22 tahun 2006 tentang standard isi untuk satuan pendidikan dasar dan menengah [Decree of the Minister of National Education No 22 Year 2006 about content standards for the primary and secondary educational unit].

Dahar, R. W. (2011). *Teori-teori belajar dan pembelajaran* [Learning theories and learning] (Ulfah (ed.); 2nd ed.). Erlangga.

Farib, P. M., Ikhsan, M., & Subianto, M. (2019). Proses berpikir kritis matematis siswa sekolah menengah pertama melalui discovery learning [Mathematical critical thinking processes of junior high school students by discovery learning]. *Jurnal Riset Pendidikan Matematika*, *6*(1), 99–117. https://doi.org/10.21831/jrpm.v6i1.21396

Gazali, R. Y. (2016). Pengembangan bahan ajar matematika untuk siswa SMP berdasarkan teori belajar ausubel [Developing mathematics learning materials for junior high school students based on Ausubel learning theory]. *PYTHAGORAS: Jurnal Pendidikan Matematika*, *11*(2), 182. https://doi.org/10.21831/pg.v11i2.10644

Hidayatullah, Z., Wilujeng, I., & Munawaroh, A. (2021). Analysis of Critical Thinking Skill Through Conceptual Change Model Learning Assisted with PhET Simulation. *International Conference on Research of Educational Administration and Management*, 627–632. https://doi.org/10.2991/assehr.k.210305.091

Juwantara, R. A. (2019). Analisis Teori Perkembangan Kognitif Piaget pada Tahap Anak Usia Operasional Konkret 7-12 Tahun dalam Pembelajaran Matematika [Analysis of Piaget's Cognitive Development Theory of the Concrete Operational Stage Year 7-12 in Mathematics Learning]. *Al-Adzka: Jurnal Ilmiah Pendidikan Guru Madrasah Ibtidaiyah*, *9*(1), 27. https://doi.org/10.18592/aladzkapgmi.v9i1.3011

Khoirunnisa, P. H., & Malasari, P. N. (2021). Analisis kemampuan berpikir kritis matematis siswa ditinjau dari self confidence [Analysis of student's mathematical critical thinking skills seen from the angle of self-confidence]. *JP3M (Jurnal Penelitian Pendidikan Dan Pengajaran Matematika)*, *7*(1), 49–56. https://doi.org/10.37058/jp3m.v7i1.2804

Lai, E. R. (2011). Critical thinking: a literature review. *Pearson's Research Reports, 6(1), 40-41*. https://www.researchgate.net/publication/297782058_Critical_thinking_A_literature_review

NEA. (2011). Preparing 21st Century Students for a Global Society : An Educator's Guide to the " Four Cs " Great Public Schools for Every Student. *National Education Association*, 6–7. https://www.academia.edu/36311252/Preparing_21st_Century_Students_for_a_Global_Society_An_Educators_Guide_to_the_Four_Cs_Great_Public_Schools_for_Every_Student

Nuryati, N., & Darsinah, D. (2021). Implementasi Teori Perkembangan Kognitif Jean Piaget dalam Pembelajaran Matematika di Sekolah Dasar Implementation of Jean Piaget's Cognitive Development Theory in the Mathematics Learning of the Primary School]. *Jurnal Papeda: Jurnal Publikasi Pendidikan Dasar*, *3*(2), 153–162. https://doi.org/10.36232/jurnalpendidikandasar.v3i2.1186

Nussbaum, J., & Novick, S. (1982). Alternative frameworks, conceptual conflict and accommodation: Toward a principled teaching strategy. *Instructional Science*, *11*(3), 183–200. https://doi.org/10.1007/BF00414279

OECD. (2019). *PISA 2018 Results (Volume I)*. OECD. https://doi.org/10.1787/5f07c754-en

Ozkan, G., & Selcuk, G. S. (2012). How effective is conceptual change aproach in teaching physics? *Journal of Educational and Instructional Studies in the World*, *2*(2), 182–190. https://avesis.yildiz.edu.tr/yayin/46110427-8a34-4bfd-8086-ebd9da049b4b/how-effective-is-conceptual-change-approach-in-teaching-physics/document.pdf

Pebriyanti, D., Sahidu, H., & Sutrio, S. (2017). Efektifitas Model Pembelajaran Perubahan Konseptual Untuk Mengatasi Miskonsepsi Fisika pada Siswa Kelas X Sman 1 Praya Barat Tahun Pelajaran

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

2012/2013 [Effectiveness of Conceptual Change Learning Model for Year X Students of State Senior High School 1 West Praya Academic Year 2012/2013]. *Jurnal Pendidikan Fisika Dan Teknologi*, *1*(2), 92–96. https://doi.org/10.29303/jpft.v1i2.241

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accomodation of scientific conception: toward a theory of conceptual change. *Science Education*, *66*(2), 211–227. https://doi.org/10.1002/sce.3730660207

Putra, I. W. E., Sadia, I. W., & Suastra, I. W. (2014). Pengaruh Model Pembelajaran Perubahan Konseptual Terhadap Pemahaman Konsep Siswa Ditinjau Dari Gaya Kognitif [Influences of Conceptual Change Learning Model on Students' Concept Understanding Viewed from Cognitive Style]. *Journal of Physics A: Mathematical and Theoretical*, *4*(2), 191–202. https://ejournal-pasca.undiksha.ac.id/index.php/jurnal_ipa/article/view/1058

Rachmawati, T. N., & Supardi, Z. A. I. (2021). Analisis Model Conceptual Change Dengan Pendekatan Konflik Kognitif Untuk Mengurangi Miskonsepsi Fisika Dengan Metode Library Research [Analysis of Conceptual Change Learning Model by Cognitive Conflict Approach to Reduce Physics Misconception by Way of Library Research Method] . *PENDIPA Journal of Science Education*, *5*(2), 133–142. https://doi.org/10.33369/pendipa.5.2.133-142

Rizaldi, D. R., Makhrus, M., & Doyan, A. (2019). Analisis Tingkat Kemampuan Berpikir Kritis Dengan Model Perubahan Konseptual Ditinjau Dari Gaya Belajar Siswa [Analysis of Critical Thinking Skills by Conceptual Change Learning Model Viewed from Students' Learning Styles]. *Jurnal Pendidikan Fisika Dan Teknologi*, *5*(1), 74–81. https://doi.org/10.29303/jpft.v5i1.794

Rohaendi, S., & Laelasari, N. I. (2020). Penerapan Teori Piaget dan Vygotsky Ruang Lingkup Bilangan dan Aljabar pada Siswa Mts Plus Karangwangi [Implementation of the Theories of Piaget dan Vygotsky in the Scope of Numbers and Algebra on Students of Islamic Secondary School Plus Karangwangi]. *PRISMA*, *9*(1), 65. https://doi.org/10.35194/jp.v9i1.886

Rohmah, N., & Z Mashuri, M. (2021). Mathematical Critical Thinking Ability in Terms of Mathematical Anxiety in Smart Card Assisted Brain-Based Learning Model. *Unnes: Journal of Mathematics Education*, *10*(20), 63–70. https://doi.org/10.15294/ujme.v10i1.41858

Setiana, D. S., & Purwoko, R. Y. (2020). Analisis kemampuan berpikir kritis ditinjau dari gaya belajar matematika siswa [Analysis of critical thinking skills viewed from students' mathematical learning styles]. *Jurnal Riset Pendidikan Matematika*, *7*(2), 163–177. https://doi.org/10.21831/jrpm.v7i2.34290

Setyosari, P. (2017). *Metode penelitian pendidikan dan pengembangan* Educational and developmental research method]. Kencana.

Syuhendri. (2017). A learning process based on conceptual change approach to foster conceptual change in newtonian mechanics. *Journal of Baltic Science Education*. http://dx.doi.org/10.33225/jbse/17.16.228

Tittle, P. (2011). Critical Thinking: An Appeal to Reason. In *Thought A Review Of Culture And Idea*.

Widayati, A.D., Triyanto, Pambudi, D. (2019). Analisis Kemampuan Problem Solving Menurut John A. Malone Dalam Pokok Bahasan Pecahan Ditinjau dari Kemampuan Awal Siswa [Analysis of John A. Malone's Problem-solving Skills on the topic of Fractions Viewed from Student's Initial Skills]. *Jurnal Pendidikan Matematika Dan Matematika (JPMM) Solusi*, *III*(4), 393–400. https://jurnal.uns.ac.id/JMMS/article/view/37695/25122

Wilujeng, I., & Hidayatullah, Z. (2021). Alternative learning model in physics learning: Effect of the conceptual change model with cognitive conflict on critical thinking skill. *Momentum: Physics Education Journal*, 111–120. https://doi.org/10.21067/mpej.v5i2.5260

Yanwar, A., & Fadila, A. (2019). Analisis Kemampuan Berpikir Kritis Matematis : Dampak Pendekatan Saintifik ditinjau dari Kemandirian Belajar [Analysis of Mathematical Critical Thinking Skills: Effects of Scientific Learning Approach Viewed from Learning Independence]. *Desimal: Jurnal Matematika*, *2*(1), 9–22. https://doi.org/10.24042/djm.v2i1.3204

ISSN 2356-2684 (print), ISSN 2477-1503 (online)