Ability of mathematical critical thinking – what about Learning Cycle 7E model?

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Abstract. Mathematical critical thinking skills of Indonesian students are still not satisfactory, which is seen when students do the problem of reasoning in solving non-routine problems. One of the alternative solutions to overcome the problem is through the implementation of the Learning Cycle 7E model. This study aims to describe enhancement of mathematical critical thinking skills of students who received the Learning Cycle 7E model. This type of research is literature review, so the method used is to summarize and analyze the relevant research results that have been done. Learning Cycle 7E model consists of seven stages, namely: elicit, engage, explore, explain, elaborate, evaluate, and extend. Each student activity at that stage involves students’ critical thinking potential, which consists of indicators: focus, reason, inference, situation, clarity, and overview. Thus, taking into account every stage of the Learning Cycle 7E on learning mathematics well will be able to improve the ability of students’ critical mathematical thinking.

1. Introduction
Critical thinking skill is one of the abilities students are expected to have in the 21st century. The American Association of Colleges of Teacher Education states that the skills students need to develop in the 21st century are skills in critical thinking, problem solving, communication, collaboration, creativity and innovation [1]. In addition, the importance of critical thinking skills is also seen in the questions given by Trends in International Mathematics and Science Study (TIMSS). The assessment of cognitive dimensions of Mathematics class IV SD and class VIII SMP in TIMSS consists of three domains of knowledge (knowing), applying (applying) and reasoning (reasoning). On reasoning domains are concerned with non-routine problem solving, complex context and multiple problem-solving steps [2]. That is, in this case required the ability to think critically mathematically students in solving non-routine problems. One of the competencies students expect after learning Mathematics at the level of SMP class VIII that students have a logical, critical, analytical, meticulous and meticulous attitude, responsive and not easily give up in solving the problem [3]. Therefore, students' critical mathematical thinking skills need to be considered in the learning process of mathematics.

However, the students' mathematical critical thinking skills are still not satisfactory. The low students' mathematical critical thinking ability can be seen from the results of the research by TIMSS in 2011, followed by Indonesian students of class VIII, where the questions tested included measuring...
students’ critical and logical thinking skills. Indonesia’s average performance in TIMSS 2011 is at a low level. The average percentage of student achievement in Indonesia is the lowest in the cognitive domain of reasoning 17% [4]. So, the critical thinking skills of Indonesian students still have to be improved, especially in solving the problem of reasoning. In addition, based on the results of TIMSS followed by fourth grade students of SD/MI, it was found that the average achievement of Indonesia in TIMSS 2015 was still at a low level, which is ranked 45 out of 50 countries with a score of 397. Based on the analysis of the acquisition results TIMSS turns out that the new Indonesian students master the questions that are routine, simple computing and measure the knowledge of contested facts all day, with 91% achievement to answer correctly. However, Indonesian students need to strengthen the ability to integrate information, draw conclusions and generalize their knowledge to other forms, in which case the achievement of 4% is correct [2]. This shows the low ability of critical mathematical thinking and the importance of improving students’ mathematical critical thinking skills. And then, based on the observation of learning in school, that one of the junior high schools in Semarang found that students’ critical thinking skills are generally low and students still have difficulty in critical thinking. The difficulty is seen from the students’ mistakes in solving math problems related to daily learning, especially about problem solving that requires critical thinking skills [5]. In addition, one of Junior High School Banjarmasin found that when observed from the work of students when doing math problems still have not seen the process of critical thinking. Thus, the critical thinking ability of students’ mathematical critical thinking is still low [6].

Based on the above problems, it is necessary for the efforts of teachers in particular to create lessons that improve the ability of students’ critical mathematical thinking. This can be done by applying lessons that can to facilitate and improve students’ analytical, evaluative and argumentative skills, thereby developing their curiosity in finding solutions to problems. One of the learning model that can be applied is Learning Cycle 7E model. Learning Cycle is one of the learning model with constructivist approach. Learning Cycle 7E learning stages are: elicit, engage, explains, elaborates, evaluates and extends. Through the Learning Cycle model students are expected to not only listen to explanations from teachers, but students also play an active role in exploring, analyzing, evaluating their understanding of the concepts studied [7]. In other words, through this learning is expected ability of students’ critical thinking can develop. Therefore, the purpose of writing this paper is to find out whether the ability of students’ critical thinking can be improved through the Learning Cycle 7E model.

2. Method
This paper is a literature review, so the method used is to summarize and analyze the results of relevant research that has been done. So as to provide information that can be used to answer research questions and in accordance with research objectives. Relevant research in this paper relates to improving the ability of students’ critical thinking through the Learning Cycle 7E model.

3. Results and discussion
Some experts put forward the meaning of critical thinking. Critical thinking is a well-directed and clear process used in mental activities such as in solving problems, making decisions, analyzing assumptions and conducting scientific research [8]. Critical thinking is a reflective and logical thinking that focuses on deciding what is believed or done [9]. The purpose of critical thinking is to achieve a deep understanding, so as to reveal the meaning behind an event. The process of critical thinking requires open mind, humility and patience [8]. In addition, one of the goals of critical thinking is to develop the perspective of learners as well as to argue that dialectical dialogue or experience is needed as an ingredient in helping develop the assessment [10]. Critical thinking is very important for science and academics. Because, science always dwells on scientific truths that will be the basis of presuppositions, and that truth can only be tested through critical thinking. In order to do the testing well so that obtained a truth, then critical thinking activities must run through argumentation, reasoning and inference [11]. Thus, critical thinking is a reflective and logical thinking in the form of a clear and directed process used in problem solving, decision making, analyzing assumptions and conducting scientific research, the
ability to argue in an organized way, as well as the ability to systematically evaluate the weight of personal opinions and opinions of others. So, critical thinking is related to the ability to analyze, evaluative and argumentative students.

Critical mathematical thinking ability is one of the essential mathematical abilities that students need to have in learning mathematics [12]. Critical thinking in mathematics is both ability and disposition by incorporating prior knowledge, mathematical reasoning and using cognitive strategies in generalizing, proving or evaluating unusual mathematical situations in a reflective way [13]. Thus, critical thinking skills are needed in solving mathematical problems. There are six basic elements of critical thinking known as FRISCO (Focus, Reason, Inference, Situation, Clarity, Overview): a) Focus, ie the student is able to identify the focus or problem center; b) Reason, ie the student is able to identify and consider the reasons for the proposed answer; c) Inference, ie the student is able to make inferences from the available information through making the steps in the settlement; d) Situation, ie students are able to answer the problem in accordance with the context of the problem, can reveal the situation or problems by using the language of mathematics and able to answer math problems application; e) Clarity, ie students are able to provide further clarity either definition or linkage of concepts; f) Overview, ie as part of the overall checking through students able to check what has been discovered, decided, considered, studied and inferred [9]. Thus, the six critical thinking elements can serve as an indicator to see students' critical thinking skills.

Learning Cycle is one of the learning model with constructivist approach [7]. Constructivism is the foundation of the contextual learning (philosophy) of learning, where knowledge is developed little by little, and the result is expanded through a limited context [14]. Students must discover and transform complex information to other situations. The task of the teacher is to facilitate the process by: making the knowledge meaningful and relevant for the students; giving students the opportunity to discover and apply their ideas; and awaken students to apply their own strategies while learning [15]. The Learning Cycle model was first introduced by Robert Carplus in the Science Curriculum Improvement Study/SCIS. In the beginning, Learning Cycle consists of three stages: exploration, invention/term introduction and concept application (discovery/concept application). Then, the three stages of the cycle are progressing. In the 1980s the Biological Science Curriculum Study (BSCS) developed it into five stages: engage, explore, explain, elaborate, and evaluate [16].

Eisenkraft developed Learning Cycle into 7 stages. Submission of Learning Cycle 7E is to develop the engage stage into two components, namely elicit and engage. Then develop two stages of elaborate and evaluate into three stages, namely elaborate, evaluate and extend. The change of the Learning Cycle 5E stage to 7E is shown in Figure 1. Thus, the learning phase of Learning Cycle 7E is: a) Elicit (bring in the students' initial knowledge). In this phase the teacher tries to remind or bring back the students' knowledge. Because new knowledge comes from pre-existing knowledge; b) Engage (interest generating/ attracting student attention). In this phase the teacher focuses students' attention, stimulates thinking ability and arouses students' interest and curiosity about the concept to be taught; c) Explore (exploration). In this phase students are given the opportunity to observe data, record data, isolate variables, design and plan experiments, chart, interpret results, develop hypotheses and manage their findings. Teachers assemble questions, input and assess students' understanding; d) Explain (explain). In this phase students are introduced to new concepts, laws and theories. Students conclude and express the results of their findings in the explore phase. Teachers introduce students to some scientific vocabulary and provide questions to stimulate students to use scientific terms to explain exploration results; e) Elaborate (apply). In this phase the teacher provides opportunities for students to apply the concepts and skills learned in new situations or different contexts, ie on issues related to the examples of the material learned; f) Evaluate (rate). The evaluation phase consists of formative evaluation and summative evaluation. Formative evaluation should not be limited to certain phases. Teachers should always assess all student activities; g) Extend (expand). In this phase, it aims to remind teachers how important the students apply their learning outcomes. Teachers need to convince students that the knowledge is applied in a new context and not limited to simple applications [17].
Each stage of the Learning Cycle 7E model enables students' mathematical critical thinking skill to increase based on student activity at that stage. The elicit stage the teacher tries to remind or re-invite the student's early knowledge, that is, the teacher raises the question, 'what do you think?'. In this condition students need to respond to the question, such as through writing and expressing the answer, while others listen for the next to respond [17]. This will involve students' critical thinking potential in the focus. Because, when a person does not focus, he does not know what he will do next [9].

Figure 1. Change of Learning Cycle 5E to 7E.

The second stage is engage, the teacher tries to focus the attention and curiosity of the students about the topic to be learned through asking questions relating to daily life about the topic to be discussed. In this case the teacher seeks to build a relationship between the students' daily experiences with the topics to be discussed [18]. Thus, the potential of critical thinking students on the reason will be involved. The reasoning stage can be a 'why' question when someone expresses an opinion. Then he gives the reason for the communication to continue. Without making excuses, one would have difficulty in making a decent decision [9].

The third stage is explore, where teachers divide students into small groups between 2-4 students, then students are given the opportunity to work together in small groups without direct learning from teachers. In this group discussion students are encouraged to test or create new hypotheses, as well as try alternative problem-solving with peer group [7]. In this phase students are given the opportunity to observe data, record data, isolate variables, design and plan experiments, graph, interpret results, develop hypotheses and organize their findings [17]. Student activity at this stage of explore is able to involve students' critical thinking potential. The focus stage of the student is able to identify the focus of the problem, which is seen when students observe and record data. The reason stage takes into consideration the reason of the answer put forward by making the settlement step, which is illustrated when designing and planning the experiment. The inference stage involves drawing conclusions from available information, which is visible when students interpret the findings. Stage situation in the form of students able to answer the problem according to the context of the problem, seen when students try alternative solutions with friends [9]. In addition, when students are experimenting with an issue, the teacher does not give instructions for the steps that the student should perform, but the teacher asks a guiding question about what the student will do, what the reason the student is planning or deciding something [7]. Thus, students' analytical, evaluative and argumentative skills will increase, so students' critical thinking skill will be involved.
The fourth stage is explain, where the teacher is required to encourage students in expressing their findings in the explore phase, asking for evidence and clarification of student explanations, as well as between students and teachers listening critically [7]. In this activity in addition to involve the critical thinking potential of students in the focus, reason, inference and situation as previously described, in this activity also involved the potential of students in providing clarity. Clarity is the ability of students to provide further clarity in both definition and conceptual relevance. This is seen when students explain the concepts they find and use observations and notes to explain them [9].

The fifth stage is elaborate, in which the teacher provides the opportunity for students to apply the concepts and skills learned in new situations or different contexts, ie on issues related to the example of the material learned [9]. At this stage, student activities include asking questions, proposing solutions, making decisions, conducting experiments, and observations [7]. When students ask, it means engaging the critical thinking potential of the students in focus, when students propose solutions, will engage reason. In the activity of making a decision will engage inference through making the settlement step. Then at the stage of doing experiments and observations will involve the potential students in the situation in the form of answering the problem, as well as in providing clarity [9].

The sixth stage is evaluation, which consists of formative evaluation and summative evaluation. Formative evaluation is not limited only to certain cycles, but teachers should assess all student activities in both elicit, engage, explore, explain, elaborate and extend stages. In this stage the teacher assesses the extent to which students' understanding of the concepts has been studied [17]. Thus, the student activity has been described previously, so that involves all the potential of critical thinking of the students, both focus, reason, inference, situation, and clarity. Because in this phase it means the teachers assess how the students understanding of each stage that has been implemented. This may look like student activity at the elaborate stage when the student proposed a solution to the problem. When students propose solutions, they will engage students' potential in reason, which ideas for the proposed answers [9].

The seventh stage is extend, where this stage is in addition to elaborate. In this case the teacher tries to convince the students that the learned knowledge can be applied in a new context and is not limited to simple applications such as in previous elaboration stages. Teachers can observe students' understanding of applying new concepts, or encourage students to ask open questions and seek answers based on learned concepts. At this stage students are also encouraged in giving further conclusions to the learning situation it does [9]. Thus, it will engage students' critical thinking potential at the overview. Overview activity is the ability of students to check what has been discovered, decided, considered, studied and concluded [9].

Based on the above description, through the stages of Learning Cycle 7E allows to improve the ability of students' mathematical thinking. Through the Learning Cycle 7E model the students' analytical, evaluative and argumentative ability can develop and increase significantly. Thus, students' critical thinking skills will increase. And then, through Learning Cycle model, it is expected that students will not only listen to the explanation from the teacher, but also actively participate in exploring, analyzing, evaluating their understanding on learned concepts. For example, at the exploring stage when students are experimenting on a problem, the teacher does not give instructions for the steps that the student should do, but the teacher asks a guiding question about what the student will do, what the reason the student is planning or deciding on his choice. This is in line with constructivist learning that teachers provide scaffolding to students in solving problems or finding a concept. Then it will cause students' analytical, evaluative and argumentative skills to develop and increase significantly [7]. In other words, students' critical thinking skills will increase.

As for some research that examines about Learning Cycle. Seen from students as a whole, improving critical thinking ability of students who received Learning Cycle 5E with Metacognitive technique is 0.62, while critical thinking ability of students who received Learning Cycle 5E is 0.49, and critical thinking ability of students who received conventional learning 0.34. This increase is in the moderate category based on the Hake classification. Thus, when viewed from students as a whole, the improvement and achievement of critical thinking skills of students who receive Learning Cycle 5E with Metacognitive techniques are better than students who receive Learning Cycle 5E and conventional
learning. Then, the improvement and achievement of critical mathematical thinking skills of students receiving Learning Cycle 5E is better than students receiving conventional learning [19].

In addition, also found that the learning model of Learning Cycle 7E can grow students' critical thinking skills seen in student activities in asking the teacher and the seriousness in carrying out the task of increasing and being in high category. Exhaustiveness of classical learning by 79%. Thus, Learning Cycle 7E can improve students' critical thinking skills in science lessons, without disturbing their cognitive learning outcomes [20]. And then, the mathematics learning achievement that received the Learning Cycle 5E model with constructivist approach is better than control class learning [18]. In addition, the Learning Cycle 7E model is more effective in improving students' Chemistry learning outcomes than students who have received conventional learning [21]. Based on the above description, it is seen that the model of Learning Cycle 7E able to improve students' critical thinking ability mathematically.

4. Conclusions

Based on the above literature, it can be concluded that each activity in the Learning Cycle 7E model stage, namely: elicit, engage, explore, explain, elaborate, evaluate, and engage enable in improving the ability of critical thinking of the students. This is reflected in the activity of each stage that contains the potential of students in mathematical critical thinking, which is in accordance with the critical thinking indicator of mathematical critical of the student. Thus, it is expected there is more research related to how much improvement ability of mathematical critical thinking through Learning Cycle 7E.

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References

[1] AACTE 2010 21st Century knowledge and skills in educator preparation [Online] retrieved from: http://www.p21.org/storage/documents/aacte_p21_whitepaper2010.pdf
[2] Ina V S M 2015 TIMSS 2015 international results in mathematics (United States: TIMSS and PIRLS International Study Center Lynch School of Education, Boston College)
[3] Peraturan Menteri Pendidikan dan Kebudayaan Nomor 64 Tahun 2013 tentang Standar Isi Pendidikan Dasar dan Pendidikan Menengah
[4] Ina V S M 2012 TIMSS 2011 international results in mathematics (United States: TIMSS and PIRLS International Study Center Lynch School of Education, Boston College)
[5] Sukriadi, Kartono and Wiyanto 2015 Analisis hasil penilaian diagnostik kemampuan berpikir kritis matematis siswa dalam pembelajaran PMRI berdasarkan tingkat kecerdasan emosional. Unnes Journal of Mathematics Education Research 4:139-145
[6] Karim and Normaya 2015 Kemampuan berpikir kritis siswa dalam pembelajaran matematika dengan menggunakan model jucama di Sekolah Menengah Pertama EDU-MAT Jurnal Pendidikan Matematika 3:92-104
[7] Made W 2009 Strategi pembelajaran inovatif kontemporer (Jakarta: Bumi Aksara) pp 172
[8] Elaine B J 2011 Contextual teaching and learning: menjadikan kegiatan belajar-mengajar menasyikan dan bermakna (Bandung: Kaifa) pp 183-185
[9] Robert E 1991 Critical thinking: A streamlined conceptioned Teaching Philosophy 14:5-24
[10] Wowo S K 2011 Taksonomi berpikir (Bandung: PT Remaja Rosdakarya)
[11] Benyamin M 2012 Logika: Ilmu dan seni berpikir kritis (Jakarta Barat: PT Indeks)
[12] Heris H, Euis E R and Utari S 2017 Hard skills dan soft skills matematik siswa (Bandung: PT Refika Aditama)
[13] Evan G 2001 Using web sources to promote critical thinking in high school mathematics [Online] retrieved from: http://www.arches.uga.edu/~eglazer/nime 2001b.pdf
[14] Ridwan A S 2013 Inovasi Pembelajaran (Jakarta: PT Bumi Aksara)
[15] Syaiful S 2011 Konsep dan makna pembelajaran: Untuk membantu memecahkan problematia belajar dan mengajar (Bandung: Alfabeta)

[16] Rodger W B 2006 The BSCS 5E instructional model: Origins and Effectiveness (Colorado Springs: BSCS)

[17] Arthur E 2003 Expanding the 5E model The Science Teacher 70 56-59

[18] Abdulkadir T and Ahmet K 2013 The effect of 5E learning cycle model in teaching trigonometry on students’ academic achievement and the permanence of their knowledge International Journal on New Trends in Education and Their Implication 4 73-87

[19] Runisah, Tatang H and Jarnawi A D 2017 Using the 5E learning cycle with metacognitive technique to enhance students’ mathematical critical thinking skills International Journal on Emerging Mathematics Education 1 87-98

[20] Hartono 2013 Learning cycle 7E model to increase student’s critical thinking on science Jurnal Pendidikan Fisika Indonesia 9 58-66

[21] Francis A A and Mabel I I 2015 Effects of 7E learning cycle model and case-based learning strategy on secondary school students’ learning outcomes in chemistry Journal of the International Society for Teacher Education 19 7-17