The Critical Thinking Skills of High School with Problem-Based Learning Model-Assisted Mind Map in Online Learning on Dynamic Fluid

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Abstract

21st-century learning is a process that emphasizes 4C attainment, namely creativity, collaboration, communication, and critical thinking. Critical thinking had a significant part in enhancing students' skills in problem-solving. The model used in the learning process affects students' critical thinking skills. The purpose of this study is to understand students' critical thinking skills in SMA Negeri 7 Surakarta on dynamic fluid material taught with a problem-based learning model-assisted mind map. This study used the descriptive quantitative method. Data were collected by giving an essay test that used five critical thinking skills indicators by Ennis. Tests were given to 30 students. The test result showed the average of critical thinking skills of students per indicator, for the elementary clarification 85.83 is very high, the basis for the decision 80 is high, inference 66.67 is high, advanced clarification 41.66 is moderate, and strategies and tactics 70.83 is high. The average critical thinking skills of all students is 69 and can be classified as a high category. Based on the test result, the critical thinking skills of 36.67% of students are moderate, 53.33% of students are high, and 10% of students are very high categorized. This research particularly provides benefits for teachers to determine the critical thinking skills of students who are taught by conducting a problem-based learning model-assisted mind map. This can be one of the recommendations for teachers in implementing learning models that support students' critical thinking skills, particularly during online learning.

Keywords
Critical thinking skills, mind map, problem-based learning, online learning, dynamic fluid.

1. Introduction

Education is a learning experience that affects individual growth throughout life and in all environments (Mudyahardjo 2013). The learning process in school involves the interconnection of various aspects ranging from teachers, students, learning resources, and the learning model. 21st-century learning emphasizes 4C achievements; one of them is critical thinking. Critical thinking is one of the learning goals for students because it will aid students in solving many problems. Application of an appropriate learning model becomes one of the ways to develop students' critical thinking skills. The choice of learning models that improved student participation in the learning process is essential, particularly in online learning. In online learning, teacher and student interaction become more difficult when using conventional learning models because teachers cannot directly see students' conditions. Therefore, to keep the students motivated and the learning objectives still be achieved is to apply a learning model that makes them actively involved. Based on the survey result conducted by Trends in International Mathematics and Science Study in 2015, it showed that students in Indonesia in the field of science are ranked 45th out of 48 countries (Prabowo and Fidiastuti 2017).

Physics which is part of science requires an enhancement in the learning outcomes of each student. Learning outcomes are related to the critical thinking skills of each student.

Based on the critical thinking skills test given previously on the physics material (rotational dynamics) during online learning using conventional learning models on 30 students of grade XI in SMA Negeri 7 Surakarta, it was obtained that the categories of critical thinking skills on students is very low 6.7%, 13% low, 40% moderate, 37% high, and 3.3% very high. This shows that improvement is needed, especially in the learning model. Hence, it can support students' critical thinking skills better. Results of interviews with physics teachers at SMA Negeri 7 Surakarta, it is known that due to the Covid-19 pandemic, online physics learning, especially in the application of experiments, cannot be carried out optimally due to media limitations. This affects students' abilities, where physics learning will be very good if supported by the implementation of experiments that allow students to understand the material because of their findings when carrying out experiments. Students' skills to think critically can be encouraged by the experiments carried out because students have to solve existing problems. One of the topics in physics requires students' critical thinking in understanding, namely dynamic fluids. Research by Fathiah et al. (2015) shows that students experience difficulties in solving problems given in dynamic fluid material. The difficulty in learning physics, especially on fluid material, was also shown in the results of the National Examination obtained by students of SMA Negeri 7 Surakarta. In the physics subject for the 2019/2020 school year, the average student score is only 56.01 with absorption in fluid material of 35.48% at the school level, 42.39% at the district level, 35.54% at the provincial level, and 31.45% at the national level. This shows the need for efforts to improve student's critical thinking skills so that maximum results are obtained.

The learning model that is applied can be adjusted to maximize students' critical thinking skills. One learning model that can be tried to be applied is the problem-based learning (PBL) model (Shofwan et al. 2021). This model makes learning centered on students. The realization of critical thinking skills for students can support by student-centered learning. Problem-based learning encourages students to resolve issues and develop skills in constructing their knowledge using various existing learning resources (Shoimin 2014). This model is supported with the help of a mind map. Mind maps are used to find solutions to problems by mapping the network of the problem (Sani 2019). Problem-based learning model-assisted mind map can be an alternative that can be applied to online learning. This will make students the center of learning, and automatically this will encourage students' critical thinking skills. Based on existing data and explanations, it is necessary to have research on how students' critical thinking skills, especially in class XI at SMA Negeri 7 Surakarta, on dynamic fluid material. This material is taught with a problem-based learning model-assisted mind map. This is done to determine the effect of a learning model on students' critical thinking skills and to allow students to become the center of learning. This research can provide input for teachers to design a lesson that can support the development of students' critical thinking skills and make the learning atmosphere more active even during a pandemic.

2. Literature Review

2.1 Critical Thinking Skills

21st-century learning has the goal of achieving 4C, namely critical thinking, creativity, collaboration, and communication (Selman and Jaedun 2020). Critical thinking skills, which is part of the achievement of the learning objectives, is an important skill for students to have. Critical thinking is reflective thinking that determines what should be done or believed (Ennis 1987). Critical thinking is the skill to analyze and evaluate information obtained from observations, reasoning, and communication to decide whether the information can be trusted to provide correct information. Critical thinking is a skill that includes knowledge activities by reviewing logical and objective aspects to obtain valid conclusions (Saputri et al. 2020). This skill is part of high-order thinking skills (HOTS). It must be based on efforts to collect the necessary information, look for reasons, and consider other people's opinions before doing something. This is by following the definition of critical thinking, which is a convergent thinking pattern that processes information from various points of view to obtain a conclusion (Sani 2019).

Thinking critically to think is a directed process used in solving problems, analyzing assumptions, making decisions, and conducting scientific research (Elaine 2009). Someone who thinks critically is a rational individual, can think reflective, and always considers when making a decision. Students' skill to think critically in the learning process is needed even up to students in college. Critical thinking of students at every level of education affects each other, so this skill must be developed as early as possible. Because this skill is very important for students, it is considered an important part of the learning process. The quality of critical thinking is a goal in learning and the quality that every graduate in universities is looking for (Wan et al. 2008). The development of critical thinking skills for students is carried out by various countries, one of which is known as the land of the white elephant. Understanding the importance of students' critical thinking led to various studies of the learning models used (Changwong et al. 2018).

A study conducted on international students at UK universities showed that they do not display the critical attitude required of learning (Shaheen 2016). Based on these results, a study was conducted on Indonesian students studying at universities in the UK, which indicated that their difficulties in facing tests at the university were related to problems of critical thinking. This is due to, among other things, a lack of critical awareness and an understanding of critical thinking concepts (Samanhudi and Linse 2019). This shows the importance of learning models in developing critical thinking skills. The skills to think critically has indicators that can be used as a reference to measure a person's abilities. These indicators are elementary clarification, the basis for the decision, inference, advanced classification, and the last, strategies and tactics (Ennis 2015). Each indicator has its sub-indicator. The learning process of students' critical abilities is needed. Good critical thinking skills are needed for every student to solve problems that occur (Istianah 2013). This skill affects student learning outcomes in every aspect of subjects, including physics. Physics is a subject that is less attractive to students, with the assumption that it is too difficult for students. Physics as part of science requires students' critical thinking skills to solve existing problems. The skills to think critically has a significant relationship with the student learning result (Husnah 2017).

2.2 Problem-Based Learning Model-Assisted Mind Map

The goal of education is not only to achieve proficiency in the academic field but also to succeed in life (Chalkiadaki 2018). Therefore, it is necessary to have a supporter that encourages the achievement of these learning objectives. One of the supporters of the achievement of these goals is the application of the learning model. The learning model that is applied affects the motivation and attitudes of students in participating in physics learning. Students who are unsatisfied with physics lessons will be less motivated to participate in the learning process Conversely, students that have a friendly approach toward physics are more motivated to learn. Students who have negative attitudes towards physics tend to dislike things related to learning, including physics courses and teachers (Guido 2013). Motivation is a very complex, multi-faceted phenomenon (Gardner 2006). This shows that external and internal factors influenced the motivation of a person. One of the external factors that can be attempted to influence student motivation is the applied learning model. This is very important to pay attention to, especially when learning takes place online because of the Covid-19 pandemic. Online learning causes student interest in learning to decrease because of a lack of interaction with other students and teachers (Yunitasari and Hanifah 2020). This also affects higher education, where students' mental health is also affected (Son et al. 2020). To overcome this, a student-centered learning model is suitable to be applied because it can increase student activeness and participation in the learning process.

One learning model that can support active student involvement in the learning process is problem-based learning. Problem-based learning is a learning model that can improve student’s critical thinking skills and learning achievement. This model is designed and developed to help students build broad knowledge and apply the knowledge gained to problem-solving (Mundilarto and Ismoyo 2017). This learning model is one of the classroom processing models needed to support the constructivist theory in teaching and learning (Warsono and Hariyanto 2012). Problem-based learning develops aspects in students such as independence, higher-order thinking skills and can also help students construct their understanding (Trianto 2009). This shows that the teacher in this model becomes a facilitator who can develop the classroom environment and support the student-oriented learning process. Problem Based Learning is a learning model that challenges students to “learn how to learn” and work in groups to find solutions to problems (Majid and Rochman 2014).

Problem-based learning (PBL) is a learning model applied by presenting problems that can stimulate students to learn. Learning with the PBL model challenges students to solve authentic problems (Birgili 2015). This shows that problem-based learning aims to activate students both from the way of thinking or thinking to solve existing problems. In practice, problem-based learning has a syntax that must be followed. This syntax is a guide for the learning process to be carried out. The syntax in this model consists of five phases; (1) orienting students towards problems, (2) organizing students to learn, (3) guiding individual and group investigations, (4) developing and presenting work, and (5) analyzing and evaluating. When orienting students to the problem, the teacher tells the educational targets and means required and motivates students to participate in selected or determined problem activities. When organizing students to learn, the teacher helps students in identifying and managing problem-related learning tasks. During the guiding individual or group investigations, the teacher encourages students to gather relevant information and conduct experiments to gain the clarity required to solve problems. At the development and presentation stages, the teacher assists students in sharing assignments and planning or preparing work due to problem-solving in the form of reports, videos, or models. And the teacher helps students in reflecting on or managing the problem processes used at the analyzing and evaluating stage (Majid and Rochman 2014).

The mind map found by Tony Buzan is one way to learn something. Mind maps are the result of the mind mapping method in the form of visualization results, can be in the form of symbols or images, which can be used instead of written notes, and the results are also easier to remember (Buzan 2006). Mind maps are one of the easiest ways to put information into the brain and retrieve that information when needed, is a creative, effective way of taking notes, and will literally "map" the mind. Mind maps are a way to improve thinking activities that can be in the form of images, where this mind map can be a substitute for notes that can improve understanding. Mind maps help increase creativity, remembering, composing ideas, solving problems, and focusing on a topic (Erdem 2017). On a conventional note, the material is written with a long list, but the mind directs to imagine a subject as an interconnected whole. Conventional records require a long list to be memorized, but the mind builds an image that can be imagined so that when the image appears in a person's shadow, all the explanations contained therein will be explained.

Physics is a subject that is less attractive to students because it is considered too difficult. Therefore, it is necessary to do various ways so that students can like physics. Problem-based learning model-assisted mind map perhaps used in physics learning to bring physics close to students. One of them is using a PBL model and the experimental method. In the current condition, experimentation is not possible in schools. Therefore, it can be circumvented by conducting virtual experiments using simulation aids. Students can still play an active role in learning and do not feel bored quickly. In addition, using a mind map can be a way for students to learn in a fun way. The effectiveness of problem-solving using the mind-map assisted PBL model is very good (Hariyanto 2015). Mind mapping helps in summarizing the results of the discussion on the learning process using the PBL model (Ravindranath et al. 2016). The application of the problem-based learning model-assisted mind map can be one way to create active and enjoyable learning.

3. Methods

The method used in this research is descriptive quantitative. The stages in this research include the planning, implementation, and final stages. At the planning stage, the researcher determines the samples and instruments used. Furthermore, at the implementation stage, an instrument test is given in the form of essay questions to students and then identifies students' answers and percentages. In the final stage, the researcher concluded the study results based on the results of the data analysis obtained. The research was carried out online, both from the learning process and also by giving tests using several applications. Online learning with dynamic fluid material is carried out using the WhatsApp application and google classroom. Students take part in learning by applying a problem-based learning model assisted by a mind map. The learning applies PBL syntax and for the experiment uses virtual experiments using PhET simulations. The sample in the study was 30 students of class XI SMA Negeri 7 Surakarta.

4. Data Collection

The research data were collected using tests. The test is one of the methods used to measure students' skills (Arikunto 2007). The test given is five essay questions. This question refers to the critical thinking indicators of Ennis (2015), and each indicator has a sub-indicator which is also the basis for the preparation of the item indicators on the test instrument. Each indicator is represented by one item on the instrument. The indicators and sub-indicators refer to the critical thinking indicators of Ennis (2015) are shown in table 1.

Table 1. Critical thinking skills

Indicator	Sub Indicator
Elementary clarification	Focus on questions, analyze arguments, ask and answer clarification questions.
The basis for the decision	Judge the credibility of a source

Inference	Make and judge inductive inferences and arguments
Advanced clarification	Define terms and judge definitions
Strategies and tactics	Decide a course of action

Data obtained is analyzed using formulas:

$$N = \frac{R}{SM} X\,100$$

Information:
N = value of critical thinking
R = obtained score
SM = maximum score

The research data were grouped into five categories according to Arikunto (2003), they are very high, high, moderate, low, and very low. The categories according to Arikunto (2003) are shown in table 2.

Table 2. Critical thinking skills category

Categories	Score
Very high	81 - 100
High	61 - 80
Moderate	41 - 60
Low	21 - 40
Very low	0 - 20

5. Results and Discussion

Data analysis is described into two types, referring to the indicators of critical thinking skills. It is elementary clarification, the basis for the decision, inference, advanced classification, and strategies and tactics (Ennis 2015). Furthermore, is an analysis of the overall data obtained by students. Results and discussions on the overall critical thinking skills of students are shown in table 3 and figure 1 as follows:

Table 3. Critical thinking skills students as a whole

Categories	Student percentage (%)
Very high	10
High	53.33
Moderate	36.67
Low	0
Very low	0

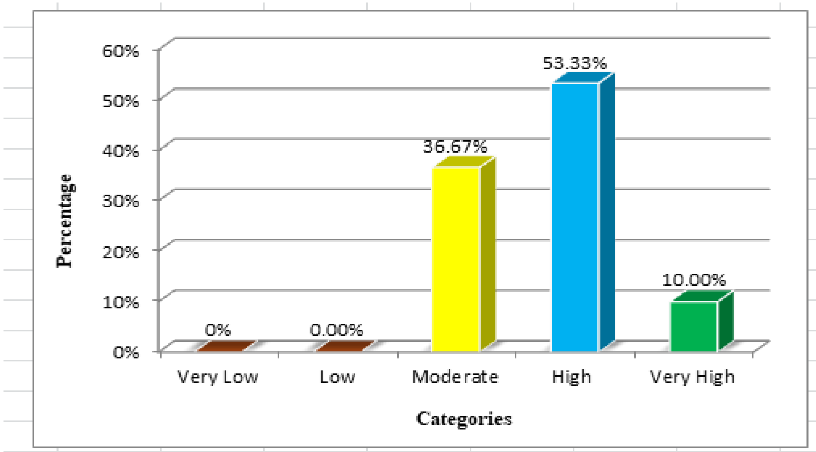

Figure 1. Result of critical thinking skills students as a whole.

The results in table 3 and figure 1 showed that the overall critical thinking skills of students in dynamic fluid material with problem-based learning model-assisted mind map are quite good. The percentage of the number of students from five categories of critical thinking skills respectively, namely 0%, 0%, 36.67%, 53.33%, and 10%. On the category of critical thinking skill, it is very low and low is 0%, which means that none of the students who took the test were included in this category. This shows that students who are taught with the problem-based learning model-assisted mind map have a significant role in critical thinking skills so that no students fall into the low and very low categories. In the medium category, the percentage of students who fall into this category is 36.67%, high is 53.33%, and very high is 10%. This shows that all students who took the critical thinking skill test taught by using the problem-based learning model assisted-mind maps were quite good. The use of this model encourages students' skills to think critically where half of the students have high critical thinking skills. These results show more significant differences with the results of students 'critical thinking skills previously in learning with conventional models wherein all categories some students fall into that category and the category of students' critical thinking skills with the largest percentage is in the medium category. The difference in critical thinking skills indicates that the model applied in this study has a significant relationship with students' critical thinking skills. This is suitable with Mundilarto and Ismoyo's (2017) research that shows this model helps students build broad knowledge and apply the knowledge gained to problem-solving. Furthermore, the results and discussions referring to the indicators of critical thinking skills according to Ennis (2015) are shown in table 4 and figure 2 as follows:

Table 4. Critical thinking skills per indikator

No	Indicator	Score	Categories	Average
1	Elementary clarification	85.83	Very high	69 (High)
2	The basis for the decision	80	High	
3	Inference	66.67	High	
4	Advanced clarification	41.66	Moderate	
5	Strategies and tactics	70.83	High	

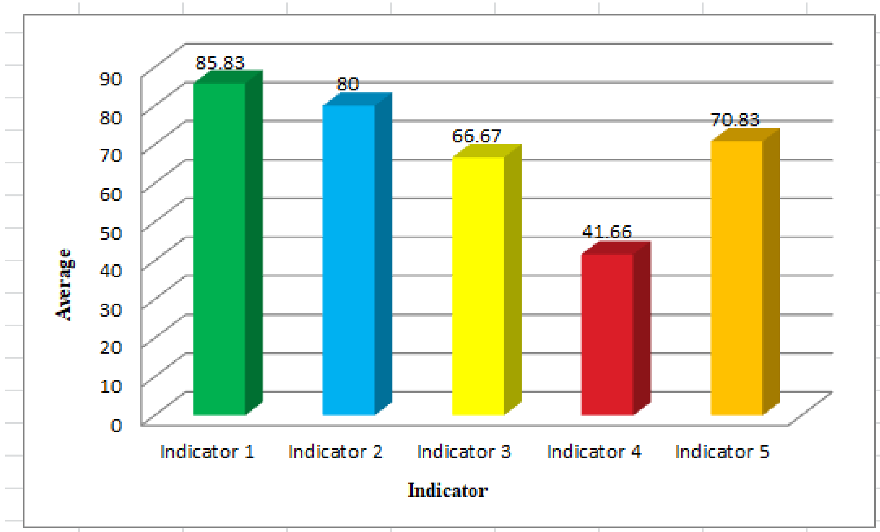

Figure 2. Result of critical thinking skills per indicator.

According to Ennis, in table 4 and figure 2, we can see the results of students' critical thinking skills in terms of five indicators. The results show each indicator, namely 85.83, 80, 66.67, 41.66, and 70.83. The first indicator, elementary clarification, has a score of 85.83 and is in the very high category. This shows that the student's critical thinking skills in solving problems that fall into the elementary clarification category are very good. In this category, students solve problems related to analyzing arguments and asking and answering clarifying questions. Students have no difficulty in this. The second indicator, namely the basis for the decision where students solve problems related to the consideration of whether a source can be trusted or not, gets a score of 80. This can be said that this indicator is in the high category, where students have no difficulty in solving the problems presented on this indicator. The third indicator, namely inference, gets a score of 66.67 and is categorized as high. In this indicator, the problem is related to inducing and considering the results of the induction, and students can solve it well. In the fourth indicator, namely advanced clarification, students solve problems related to defining terms and considering definitions. The score obtained by the students was 41.66 and categorized as moderate. This shows that on this indicator, students experience greater difficulties than other indicators. While on the fifth indicator, namely strategies and tactics where students solve problems related to deciding on an action students solve well. The score obtained by the students was 70.83 and was included in the high category. According to the grouping used, the indicator of critical thinking skills with the highest achievement is the elementary clarification of 85.83, which is categorized as very high, while the lowest is in the advanced clarification category of 41.66, which is categorized as moderate. Advanced clarification indicators have a high level of critical thinking processes. This makes solving the problem at this indicator more difficult. Students need to think hard to solve the problem. Overall, the average critical thinking skills of students was 69 and it was in the high category.

The application of problem-based learning model-assisted mind map in its implementation during the learning process makes students active. This is in line with the results, which show that the problem-based learning assisted mind map model affects students' scientific attitudes, including those related to activeness (Novita et al. 2020). At the time of implementing virtual experiments, students retrieve data by conducting experiments using the simulations provided. The activeness of students in asking questions and communicating with friends and teachers allows students to solve existing problems and prove existing formulas. When implementing learning according to the syntax of the problem-based learning model, students follow all the processes well, starting from presenting the problem, determining problem formulations and hypotheses, collecting data, analyzing, and drawing conclusions. Presentation of results and discussions can be followed well by students even though they are online. This also affects students' understanding because, in the discussion process, students are active in presenting their opinions according to the results of their work. In addition to building their knowledge, students are allowed to make a mind map of what they have learned. This gives independence to each student to express what has been understood and also reduces students' boredom; because by making a mind map, students can create according to their creativity. The student's skills to help students solve problems on problems as proposed by Shoimin (2014) are assisted by the learning model used, where problem-based learning encourages students to solve problems and develop skills in constructing their knowledge using various existing learning resources.

The model used is very influential in learning, such as in studying physics, because it affects students' skills in solving problems that are relevant to their lives (Argaw et al. 2017). Based on the results of the analysis above, it can be seen that the problem-based learning model-assisted mind map can be one of the models applied in learning to support students' critical thinking skills. This is in line with Novita et al.'s (2019) research, where the application of the problem-based learning model using a mind map can improve students' critical thinking skills and problem-solving skills. This shows between PBL model-assisted mind map and critical thinking skills have a significant relationship. It is known that critical thinking is a convergent thinking pattern which is the process of processing information from various points of view to obtain a conclusion (Sani 2019). The skills to process this information is supported by a problem-based learning model that encourages students to solve problems and develop skills in constructing their knowledge using various available learning resources (Shoimin 2014) with the help of a mind map to make it easier to remember things (Buzan 2006). This mind map makes it easy for students to understand a material because making it starts from making the main idea to other parts helps students generate a material (Joao and Silva 2014). The combination of PBL and digital mind maps can be used to support students' critical thinking skills and creativity simultaneously (Hidayati et al. 2019). However, it still needs to be maximized again so that the skills to think critically on each indicator have the same achievement. Each indicator of critical thinking skills put forward by Ennis has a different level of difficulty. Therefore, it needs to be developed again so that when the questions on these indicators can be resolved properly. This shows, with the application of an appropriate model, students' critical thinking skills can still be maximized even in different learning conditions. Based on this research, the application of this model is also expected to reduce students' negative views about physics, thus making this subject more attractive. Students can learn with enthusiasm, not get bored, and remain critical even in online learning. This research also shows that the role of teachers is to become more innovative in design learning, especially when online learning so that there are no significant discrepancies between student understanding when learning takes place at school or online.

6. Conclusion

Based on data analysis and discussion, it can be concluded that the critical thinking skills of grade XI in SMA Negeri 7 Surakarta on dynamic fluid that taught with problem-based learning model-assisted mind map is 69, it can be classified in high categorized. The results also show students' critical thinking skills per indicator can be classified into very high, high, and moderate categorized. Some of the indicators of critical thinking skills can be improved so that each indicator of that critical thinking skills can be well accomplished by each student. Based on this research, it can be concluded that problem-based learning model-assisted mind map can be one of the models used to support an effort to maximize students' critical thinking skills, and teachers can use this model, especially during online learning.

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