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Exploring Students' Critical Thinking Skills with A Problem-based Learning Model Assisted by Animated Video in Static Fluid Learning

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Abstract

This study was motivated by the necessity of improving students' critical thinking skills in the era of Industry 4.0. We developed and implemented a problem-based learning model (PBL) assisted by animated video as a learning tool made by using Adobe After Effects to improve the critical thinking skills of high school students using Problem-Based Learning as the instructional model in static fluid learning. This study applied a quasi-experimental one-group pretest-posttest design with a quantitative approach and purposive sampling. This study's samples included students of Class XI MIPA 3 of one of the high schools in Samarinda. This study's instrument consisted of essay questions about static fluids in physics that contained six indicators of critical thinking abilities: (a) identifying problems, (b) giving arguments, (c) deductive reasoning, (d) inductive reasoning, (e) evaluating, and (f) problem-solving and decision making. The results show that it is feasible and effective to adapt animated videos as learning media for educational content to improve students' critical thinking skills. The most improved aspect was on the deductive reasoning with an average N-Gain score of 0.93 by a 78-point difference between the pretest and posttests, and the least improved aspect was on the inductive reasoning aspect with an average N-Gain score of 0.63 by the 38-point difference between the pretest and posttests and an Effect Size of 3.43 in the very large category. We conclude that improving students' critical thinking skills using a problem-based learning model assisted by animated video in static fluid learning is effective.

Keywords: Animation; Critical Thinking; Problem-Based Learning

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INTRODUCTION

Critical thinking skills (CTS) are essential daily, especially in the current Industry 4.0 era. Critical thinking skills are a priority for students in almost every academic institution (Boa et al., 2018; Rear, 2019). They not only help students get good grades in their studies but also help them achieve success and solve their real-life problems in the future. Students with critical thinking abilities can analyze their thoughts to make decisions, draw conclusions, and solve real-life problems (Rüütmann, 2019; Sasson et al., 2018). Additionally, critical thinking enables students to manage various

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personal responsibilities effectively (Robinson & Knight, 2019; Zhang et al., 2020). Retnowati et al. (2018) define critical thinking as improving the quality of one's logical thinking by modifying its structure and applying intellectual standards. Despite the importance of critical thinking skills, many schools in Indonesia still need to adequately prepare their students due to their low critical thinking skills (Fitriani et al., 2022; Zubaidah et al., 2018). Therefore, students' critical thinking skills need to be improved, including problem identification, argumentation, deductive and inductive reasoning, evaluations, problem resolution, and decision-making aspects.

The implementation of the problem-based learning model is capable of enhancing students' critical thinking skills. The PBL model is a learning strategy that presents problems closely associated with actual, significant cases or events (Kusmawan et al., 2020; Roberts et al., 2022). It has commonly been used to stimulate critical thinking skills since its syntax correlated with the critical thinking skill indicators. PBL has the potential to stimulate the development of critical thinking through problem-solving, facilitate group work, facilitate the discovery and evaluation of research materials, and promote lifelong learning (Tan, 2021). PBL was used in this study because it has been proven to foster the improvement of students' critical thinking skills through reasoning, analysis, problem-solving, decision-making, argumentation, interpretation, synthesis, evaluation, and independent learning (Aswan et al., 2018; Moallem et al., 2019).

Learning media is another factor that contributes to improving students' critical thinking skills. It is an essential instrument for determining the efficacy of the teaching and learning process as it facilitates interaction between teachers and students. It dramatically influences students' ability to comprehend learning, motivation, and student learning outcomes (Hamid et al., 2020; Tafonao, 2018). Innovations in learning media may help students think critically, so it can be a solution to promote the development of student's critical thinking skills.

The education sector has been affected by the post-pandemic condition. Some institutions have implemented a face-to-face learning system, some use an online one, and others use a blended one. Students needed help keeping up with the learning materials and system. Teachers need teaching and learning strategies compatible with various teaching and learning models to be applied even if the school system changes. During the pandemic, the quality of education, including students' critical thinking skills, was relatively low (Duri et al., 2021; Mustari, 2022; Serevina & Luthfi, 2021). Therefore, the PBL model and animated video were needed as a CTS-enhancing learning model and learning media to make the learning material easier to comprehend. Videos can accommodate nearly all forms of educational content (Kusmawan et al., 2020). The implementation of animation and simulation of various phenomena and events in students' everyday lives can make abstract concepts more concrete and make it easier for students to understand them (Çelik, 2022; Djamas et al., 2018).

Animated videos can be used synergistically to complement various learning models. It can also be applied to face-to-face learning systems, online learning systems, and blended learning systems. It is one of the audio-visual learning media. Audio-visual media can increase student engagement in learning activities (Thesarah et al., 2021; Yeh, 2022). Animated video meets the criteria of the learning media needed at this time, making it a flexible and proportional learning media since it can be

implemented on many occasions in the current educational situations. It is also an effective instrument for supporting the learning process, including mass, individual, and group learning (Vioreza et al., 2020).

Teaching and learning strategy with the PBL model assisted by animated video has many advantages. The PBL model helped students think critically while analyzing and solving daily problems. At the same time, animated learning videos aided students' understanding of abstract scientific concepts by providing vivid illustrations of how a phenomenon occurs (Kelch et al., 2021). It also made learning fun, practical, and accessible while visualizing things that cannot be seen bare-eyed (Lestari, 2019; Simarmata et al., 2020). Adobe After Effects is the software used to create animated videos. Adobe After Effects offers various compelling, advanced, and popular visual effects, even among professionals. It has more visual effects than similar software and specialized tools and extensions, such as plug-ins, expressions, and scripts (Christiansen, 2013). The capabilities of animated video, along with the flexibility and customizability of Adobe After Effects, allow the creation of animated videos that support the exploration of students' critical thinking skills (Wulansari Ramadhany et al., 2022; Yuliana et al., 2020).

Other studies related to PBL, CTS, animated video as learning media, and audio-visual learning media, in general, have been reported. Some of them were found in Fidan & Tuncel (2019), Ritonga et al. (2020), Simanjuntak et al. (2021), and Faridi et al. (2021). However, exploring each indicator of students' critical thinking skills from problem-based learning assisted by animated video in the static fluid topic has yet to be conducted (Churiyah et al., 2020). Therefore, we conducted this study to teach students about the static fluid topic using a problem-based learning model assisted by animated video and exploring each aspect of their critical thinking skills.

METHOD

This research was conducted using a quantitative approach with a quasi-experimental research method and a one-group pretest-posttest design (Gliner et al., 2017). Samples were chosen through purposive sampling. They were given a pretest before the treatment and a posttest after the treatment. The treatment consisted of four meetings of learning sessions and a total of six meetings, with two meetings as pretest and posttest. The questions on the pretest and posttest are based on six aspects of critical thinking skills (identifying problems, giving arguments, deductive reasoning, inductive reasoning, evaluation, and problem-solving and decision-making). The instrument questions in this study were adapted from previous research by Susanto (2021), which had been modified according to research needs by following the curriculum, topics, and learning strategies. The questions are in the form of essays about static fluid materials in physics. This research focuses on students of class XI MIPA 3 of one of the high schools in Samarinda.

Learning activities were arranged according to the PBL model, assisted by animated videos using Adobe After Effects while considering the indicators of critical thinking skills (Mebang et al., 2021; Suardi, 2018). The lesson plan fulfills the PBL syntax and six critical thinking skills (CTS) indicators. Given that, the students will be given worksheets to discuss in groups. Worksheets contain events and phenomena related to fluid in the form of animation, questions related to the animation that are based on indicators of critical thinking skills, and evaluation questions related to the material being studied. The process of the learning

activities is shown in the following flowchart in Figure 1.

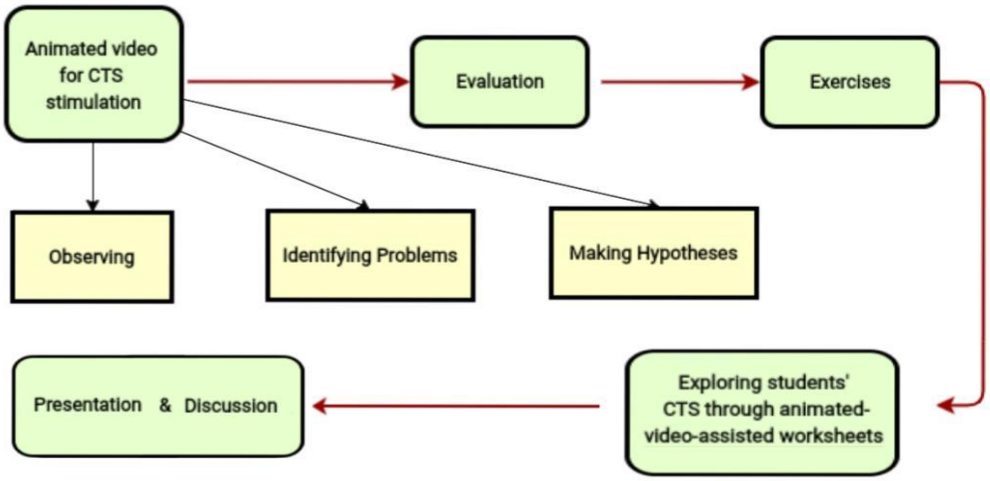


Figure 1 Learning activities flowchart

To explore critical thinking skills, Higher Order Thinking Skills (HOTS) questions are used, as shown in Figure 2.

Question No. 1 :

Printer users often experience printer ink being unable to come out of the cartridge when it has not been used for a long time. This happens because the ink thickens, resulting in greater friction with the cartridge gap. What can be done to solve this problem, and what solutions can be taken to prevent this from happening again?

Ideal complete answer :

The clogged printer ink in the cartridge is caused by ink clumping, so it has a high viscosity. As a result, the friction with the cartridge hole is getting bigger. The possible solution to the problem is to dilute the ink again, namely by soaking the cartridge in warm water or a special liquid to dilute the ink or cartridge cleaning fluid. Another alternative solution that can be given so that this incident does not recur is to remove air cavities in the cartridge, which causes the ink not to come out or get stuck, and to use the printer regularly so the ink does not clot.

Figure 2 Question no. 1 and the ideal complete answer

The critical thinking skill explored based on Question No. 1 is solving problems and making decisions. Specific results that can be obtained by students, especially from Problem No. 1, include the skill to solve problems based on the results of evaluating cartridge problems and making decisions that can be taken to solve problems so that the cartridge can be used and prevent the cartridge from jamming again. Based on Question No. 1, students can define the problem, look for possible solutions that meet the criteria, provide alternative solutions, and decide what to do based on a logical strategy.

Question No. 2:

Two professional divers, Akbar and Bayu, often practice in the sea and river. One day, Akbar was diving in the sea, and Bayu was diving in the river. Both reach the same depth when measured from the surface of the water. In your opinion, which one will experience greater water pressure, and why can this happen? Give your opinion regarding the similarities and differences between Akbar, who dives in the sea, and Bayu, who dives in the river, regarding static fluid matter!

Ideal complete answer :

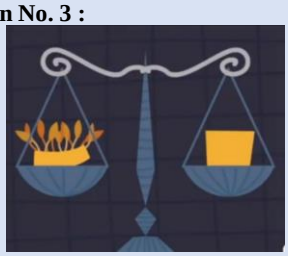
Hydrostatic pressure depends on the density of the fluid, in this case, water. Sea water (saltwater) has a higher density than river water (freshwater); therefore, for the same depth, people who dive in the sea will experience

greater hydrostatic pressure than those who dive in the river. From the illustration of the problem, Akbar feels greater pressure. So, according to the hydrostatic pressure equation, $Ph = \rho gh$. Based on this, we know that the equation between Akbar and Bayu is that both experience hydrostatic pressure, which is influenced by depth, the density of seawater for Akbar, the density of river water for Bayu, and gravity. The difference is that the hydrostatic pressure experienced by Akbar and Bayu is different due to the difference in the densities of seawater and river water fluids.

Figure 3 Question no. 2 and the ideal complete answer

The critical thinking skill that can be explored based on Question No. 2 is the ability to make arguments. From this problem, students can develop skills to state and give reasons that an idea is true in terms of evidentiary considerations, such as associating it with applicable laws related to static fluids and the contextual basis of the result, and present their reasoning as a convincing argument. Based on these sample questions, students can process ideas, identify arguments, identify reasons and statements, and provide evidence to support their arguments.

Question No. 3 :



King Hieron II gave two gold bars to a goldsmith. One to make a crown and one to pay the goldsmith. The crown must be made of pure gold without mixing it with materials or adding gems. After weighing, the mass of the gold bar and crown were the same, but the King still doubted the honesty of the gold craftsmen. Archimedes received an assignment from King Hieron II to investigate whether the king's crown was made of pure gold or mixed with silver. When weighed, the crown has the same mass as the gold bar. Archimedes devised a very creative idea by immersing the king's crown in a water vessel. After that, Archimedes also immersed another gold bar, identical to the one given to make the crown material, into another identical water vessel. Based on the story's illustration, how can we know if the king's golden crown is made of pure gold by associating it with the laws and principles about static fluids?

Ideal Complete Answer :
Two identical gold bars have the same density, mass, and volume. If the king's golden crown is made of pure gold, without any mixture, then the crown's density, mass, and volume will be the same as the gold bar. The volume of water in the two vessels is identical, which means that if you put the same amount of identical matter in each, the rise in the water level or the displacement of the water will be the same. If the crown is immersed in one vessel, the gold bar is immersed in another, and the displacements of the water are the same, then the crown is indeed made of pure gold. Whereas if the water displacements are different, then the crown is not made of pure gold. This is because the density of an object is proportional to its mass per unit volume. Suppose the masses of the two objects are the same, but the volumes of the two objects are different (as seen from the different displacements of the water). In that case, the densities of the two objects are different, which means that the gold crown was mixed with other materials.

Figure 4 Question no. 3 and the ideal complete answer

The critical thinking skill that can be explored based on Question No. 3 is deductive reasoning. With this question, students can use premises and general ideas to determine the authenticity and purity of a gold crown. Based on the sample questions, students can reason deductively from the accepted or rejected premises. Students collect existing related theories, formulate hypotheses, collect data, analyze the data, and then accept or reject hypotheses. Students predict results based on existing facts.

To test and measure students' critical thinking skills and the improvement of each indicator, the N-Gain test developed by Hake (1999) was used on the pretest and posttest scores, while to test how effective the PBL model assisted by

video animation was in improving students' critical thinking skills, the Effect Size test developed by Cohen (1988) was used as an analysis technique with the help of statistical data processing software IBM SPSS 25 and Microsoft Excel 365.

RESULT AND DISCUSSION

The phases of the PBL, students' problem orientation, organizing students for study, independent and group investigation, works development and presentation, and problem-solving process analysis and evaluation (Arends, 2012), were achieved throughout the teaching and learning activity. Students' problem orientation was achieved during the teaching and learning activity's beginning and the fourth step by observing the animated video, identifying a problem, making hypotheses, and using animated-video-assisted worksheets. The second phase was achieved through the teacher's help for the students to define and organize study tasks related to the problem. In the third phase, the teacher encourages students to gather information and search for explanations and solutions independently and as a group through discussion. In the next phase, students plan and prepare appropriate artifacts and share their work with others. In the final phase, the teacher helps students to reflect on their investigations and the processes they used.

The data of the pretest and posttest show that the PBL model assisted by animated videos made with Adobe After Effects is feasible and efficient. The critical thinking skills of high school students can be improved through the animated video-assisted PBL model, with the deductive reasoning aspect showing the highest improvement with an N-Gain score of 0.93 (with a mean difference between the pretest and posttest of 78 points). The lowest improvement is in the inductive reasoning aspect, with an N-Gain score of 0.63 (with a mean difference between the pretest and posttest of 38 points).

Students' scores were identified by measuring the normalized gain (N-Gain) value, which has increased. The results of the average pretest score, average posttest score, and average N-Gain score for class XI MIPA 3 of one of the high schools in Samarinda are shown in Table 1, followed by the percentages of each category of N-Gain scores and N-Gain scores for each indicator of critical thinking skills in Table 2 and Table 3. The size of the practical significance of improving students' critical thinking skills is shown by Cohen's d Effect Size between the posttest and pretest scores shown in Table 2 as follows.

Table 1 N-Gain score

Pretest score means	Posttest score means	N-Gain score	Category
19.92	84.54	0.81	High

Source: Processed primary data, 2022

Table 2 Percentage of each category of N-Gain Score

N-Gain score	Category	Frequency	Percentage	Effect Size
$g \geq 0.70$	High	28	75.68%	
$0.30 \leq g < 0.70$	Moderate	8	21.62%	3.43
$g < 0.30$	Low	1	2.70%	

Source: Processed primary data, 2022

Table 3 Percentage score for each critical thinking skills indicator

Critical Thinking Skills Indicator	Pretest		Posttest	
	Percentage (%)	Criteria	Percentage (%)	Criteria
Problem Identifying	39.5	Low	77.8	High
Making Arguments	20.3	Very Low	79.2	High
Deductive Reasoning	20.7	Very Low	80.9	Very High
Inductive Reasoning	17.8	Very Low	82.7	Very High
Evaluating	16.8	Very Low	88.2	Very High
Problem Solving and Decision Making	15.8	Very Low	93.9	Very High

Source: Processed primary data, 2022

The effect size of the pretest and posttest is 3.43, which is included in the very large category. Based on these measurements, it can be concluded that the measure of the effectiveness of making animated videos using Adobe After Effects learning media on static fluid material to improve students' critical thinking skills is very large.

Based on the pretest and posttest score data, the PBL model and video animation learning media with Adobe After Effects effectively improve students' critical thinking skills, with an Effect Size value of 3.43. Based on these measurements, it can be concluded that the effectiveness of making animated videos using Adobe After Effects learning media on static fluid material to improve the critical thinking skills of high school students is very large. This research is supported by Cahyanto et al. (2022) which indicates an increase in test results with an N-gain value of 0.68, or in the medium category. Meanwhile, the Effect Size of Astra et al. (2021), which implements an active learning model of the team quiz type assisted by video animation, is 3.588, which is classified as a major effect. The findings of previous studies stated that teachers can use animated videos to improve high-level thinking skills (Rahmawati et al., 2021). Other research also states that using animation-based learning made with Powtoon with the scientific approach is capable of improving thinking skills critical of students in learning physics (Nafiah et al., 2021)

The indicator of critical thinking skills with the lowest score before treatment was deductive reasoning, with a score of 15.8 out of 100. The indicator with the highest score for critical thinking skills after treatment was deductive reasoning, with a score of 93.9 out of 100. This shows that the highest increase in critical thinking skills scores was found in the deductive reasoning indicator, with an increase of 78.1. The indicator with the highest critical thinking skills score before treatment was inductive reasoning, with a score of 39.5 out of 100. The indicator of critical thinking skills with the highest score after treatment was also deductive reasoning, with a score of 77.8 out of 100. This shows that the lowest score increase was in reasoning inductive indicators of critical thinking skills, with an increase of 38.4. The increase in the average score for each indicator between before and after treatment is 62 out of 100 points.

Improved indicators of critical thinking skills from lowest to highest sequentially after treatment are inductive reasoning, problem-solving and decision-making, argumentation, evaluation, problem identification, and deductive reasoning. During learning activities, students carry out problem analysis regarding static fluids, connect

relevant general knowledge from long-term memory to solve specific questions or problems for discussion, and work on worksheets after being given event descriptions and animated videos. Students are always directed to formulate problems in the form of questions by asking questions directly or making notes after watching each animated video. With this treatment, students become accustomed to connecting generally accepted facts to produce specific information. This makes the aspect of deductive reasoning experience the highest increase among other aspects, followed by formulating problems with the second highest increase. Critical thinking skills can be increased with PBL through the stimulation provided by the teacher so that students can formulate problems, provide arguments, perform deductive and inductive reasoning, evaluate, solve problems, make decisions, and draw conclusions from the phenomena being analyzed and discussed.

These findings are supported by prior studies such as Riyanto et al. (2020), Simanjuntak et al. (2021), Syawaludin et al. (2019), and Yakob et al. (2020). It is reported that PBL combined with computer simulation could help improve students' problem-understanding and develop problem-solving and creative thinking skills (Simanjuntak, 2021). Multimedia, especially animated video, has significantly improved critical thinking skills (Riyanto, 2020; Syawaludin, 2019; Yakob, 2020).

CONCLUSION

The study results show that applying the PBL model assisted by video animation is a feasible and effective learning medium for improving students' critical thinking skills. The level of students' critical thinking skills after learning with the PBL model and animated videos is higher than before learning with the PBL model and animated videos. The six aspects of critical thinking skills are shown to increase with an average increase of 60 out of 100 points. The aspect that improved the most was deductive reasoning, with an N-Gain score of 0.93 and a difference of 78 points between the pretest and posttest. The aspect of inductive reasoning has the lowest improvement, with an N-Gain score of 0.63 and a difference of 38 points between the pretest and the posttest. The PBL model assisted by video animation shows enormous effectiveness, as indicated by the Effect Size value of 3.43. It implied that this learning strategy is most effective for increasing aspects of students' deductive reasoning in critical thinking. The PBL method assisted by animated video can be considered a learning strategy in the industrial era 4.0, particularly in preparing future generations capable of analyzing, solving problems, and having responsibility.

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