

# Enhancement of Students Critical Thinking Skills Through Problem-Based Learning Multimedia

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**Abstract:** This study aims to enable the readers to evaluate and analyze the different types of results of various research that identify the effectiveness of multimedia-based PBL to improve critical thinking skills. This study is a descriptive qualitative study with a critical discourse analysis approach. The data are taken from various studies with the same theme and were compared with various expert opinions through in-depth literature. This study evaluates the results of research by Kurniawati & Suryadarma (2015), Isnaeny et al. (2018), Munandar et al. (2018), and Nirbita et al. (2018). The researcher conducted a literature review and compared the results of the study with various expert opinions. From some of these studies, there are positive aspects that can be taken, namely (1) the formulation of research objectives must obvious; (2) data in background must be using international research data and official data from national ministries, observations, questionnaires, and other research results; (3) research methods are explained in detail; (4) the stages of implementation of the media are described; (5) research results data are presented with tables or graphs that are easy to understand; (6) discussion of research results must be accompanied by expert opinions; and (7) conclusion of the research must be accompanied by an explanation of the strengths and weaknesses of the media users on the research. Furthermore, the results of this study can be used as guidelines and reinforcement of the theory that multimedia in PBL environments can increase the skills to think critically.

**Keywords:** *multimedia, problem-based learning, critical thinking skills, literature review*

## INTRODUCTION

Thinking skills are one of the life skills that need to be developed through an educational process because they can determine the success of everyone's life. Barell (2003) states that critical thinking skills are an important element that must be achieved by implementing a learning curriculum. Fisher (2008) defines critical thinking as a skilled activity that demands interpretation and evaluation of observation, communication, and sources of information and it's guided by intellectual standards in the form of clarity, relevance, adequacy, coherence. According to Paul & Elder, critical thinking is analyzing and evaluating thinking to improve it in other words, independent thinking, discipline, self-monitoring, and self-correction (Mutakinati, 2018). Furthermore, critical thinking skills are defined as a thinking process that requires high cognitive processes through analyzing problems, making arguments, evaluating, making decisions, and problem-solving (Suwono et al., 2017; Karakoc, 2016).

Students who have the skills to think critically can ask questions well, provide effective and efficient information, make rational decisions from something that is trusted or unbelievable (objective), and have conclusions that are consistent in solving a problem (Bustami et al., 2018; Fakhriyah 2014; Cahyarini et al., 2016). The indicators of critical thinking skills according to Fascione (2015) include interpretation, analysis, inference, evaluation, explanation, and self-regulation. Surasa et al. (2017) state that learning that can improve students 'critical thinking skills is by providing meaningful concepts and using active teaching methods, and involving students' skills to make rational decisions in complex situations.

The facts in the field show that critical thinking skills in Indonesia are still low. Based on a survey from the World Economic Forum (WEF), the Global Competitiveness Index (GCI) Indonesia in 2016-2017 is ranked 41st out of 138 countries, under GCI Malaysia and Thailand. This is influenced by the education level of Indonesian workers, especially aspects of critical power abilities and skills to think analytically (Hidayah et al., 2017). Based on observations in class B of 5th grade Muhammadiyah 8 elementary school shows that teacher still does not involve students in the learning process. the teacher only uses media books/modules. Furthermore, teachers still dominate learning with lectures and the use of expository models in each lesson. The study of documentation regarding the midterm assessment data shows that 11 students from 29 students or around 38% of the total students get scores under the minimum completeness criteria. The average class score is still below from the minimum completeness criteria, which is 73 while the Class 5th minimum completeness criteria are 75.

This is supported by data from various studies that show that critical thinking skills in Indonesia are still low, including research by Hasan et al. (2013) in elementary school students in Ternate and Suryanti et al. (2018) in Surabaya. In high school junior students studied by Fuad et al. (2017) in Kediri and Marlina et al. (2018) in Sumatra. Research on senior high school students reviewed by Setiawati and Corebima (2017) in Pare-Pare, and research on university students in Indonesia reviewed by Mahanal et al. (2016) and Ashari et al. (2016).

Student's low critical thinking skills, if not handled properly, will harm them to the next level. Students will not be able to develop their knowledge in dealing with everyday problems and have an impact on the quality of education in Indonesia. Therefore, to build critical thinking skills, teachers should present modern learning, active inquiry, and explore problems (Changwong, 2018). The solution to resolve the student's low critical thinking skills is by applying innovative media and learning models.

The use of learning media can help students understand the material effectively and efficiently, so students can construct their knowledge and improve thinking skills and clarity of communication is greater (Omenge & Priscah, 2016; Naz, 2008). Learning media that are effectively used in learning are multimedia. Agnew et al. (1996) define multimedia as an activity to see and hear complex presentations that require audio cassette players, slides, films and all of that under computer control. Briefly, Ogren et al. (2015) define multimedia as material that presents information in various formats, such as text, images, diagrams, and formulas in a single unit. Multimedia is a combination of various types of digital media such as text, images, sounds, and videos being interactive applications or presentations by presenting verbal and non-verbal information in a fun way and has aesthetic value (Molinaa et al. 2018; Khoiriah et al. 2016). Multimedia provides an interactive way of representing information and encourages students' thinking through a learning process by presenting abstract concepts explicitly, and providing a richer and more diverse environment that brings students closer to reality (Waey & Masood, 2014; Ilhan & Oruc, 2016).

Furthermore, the learning model can also facilitate students to think critically is problem-based learning. Boud & Felletti (1997) define PBL as an approach to compile a curriculum that involves students in dealing with problems through practice as a stimulus for learning. states that the essence of PBL is to present situations in the form of authentic and meaningful problems to students as a springboard for investigation. Fakhriyah (2014) defines PBL as a learning model that uses real problems encountered in the environment to gain knowledge through the skills to think critically and solve problems with various solutions, and can identify causes.

PBL not only provides with knowledge but also increases cognitive learning outcomes, problem-solving skills, critical and creative thinking, communication, teamwork, and self-evaluation through the stimulus of studying real-world problems to motivating students to become lifelong learners (Anazifa & Djukri, 2017; Suwono et al., 2017).

Many studies that state the relationship or influence or effect of PBL on students' critical thinking skills, and research that states the influence of multimedia on students' critical thinking skills. However, few theories that state multimedia in PBL or multimedia-based on PBL affect the students' critical thinking skills. This research is a theory presentation, research methods that can be used until the results of the research are studied in depth so it can be used as a reference for research on the same theme, namely the use of multimedia-based on PBL. Therefore, this study aims to analyze the results of several research that identify the effectiveness of multimedia PBL-based to improve critical thinking skills.

## **METHOD**

This research is a descriptive qualitative study with a critical discourse analysis approach. According to Moleong (2005), qualitative research is research that produces descriptive data in the form of written or oral words from people and observable behavior. According to Badara (2012), critical discourse analysis is an in-depth study that seeks to uncover activities, views, and identities based on the language used in the discourse. This study compares various studies with the same theme, namely the use of problem-based multimedia on the skills to think critically with various expert opinions through in-depth literature.

## **RESULTS AND DISCUSSION**

This article's discussion is divided into two: (1) enable the readers to understand and evaluate the different types of research for use of problem-based multimedia learning; and (2) analyzed the results of various studies that identify the effectiveness of PBL based multimedia to improve critical thinking skills. At the next stage, the researcher will review the results of the research and add some expert opinions according to the review. The results of the study examined the use of multimedia-based problems and their influence on critical thinking skills by Kurniawati & Suryadarma (2015), Isnaeny et al. (2018), Munandar et al. (2018), and Nirbita et al. (2018).

Multimedia is a media that in its application must use a computer as a tool. Kurniawati & Suryadarma (2015) examined the effectiveness of computer-assisted learning media for PBL on high school critical thinking skills. The purpose of this study was (1) to analyze the feasibility of computer-assisted learning media based PBL, and (2) the effectiveness of instructional media to improve critical thinking skills. The background of this study has been supported by data on student's low critical thinking skills from the TIMSS 2011 study (Trends in International Mathematics and Science Study), then data from an interview with teacher, and analysis of student's biological scores on the 2010/2011 National Examination results. Then, followed by the explanation of the theory of PBL and computer-assisted learning media.

This research is development research adapted from the ADDIE model including analysis, design, develop, implement, and evaluate. The analysis phase consists of an analysis of competencies, student characteristics, and learning. The design phase is product design. The development stage begins with making media as product 1, assessed by media and material experts, then revising and manufacturing products 2. The implementation stage is a limited stage of product testing, then field product testing. Finally, the evaluate stage consists of a

broad-scale assessment and product revision. The instruments used in this study were questionnaires, critical thinking skills tests, and observation sheets.

The product evaluation data was carried out by two substance experts, one media expert, four Biology teachers, and five colleagues showed that the average score was very good (A). Then, a limited trial conducted to see the read skills of computer-assisted learning media for problem-based learning by students showed excellent results (A). Field trials consisting of the implementation of the Learning Implementation Plan showed 80% results, students' responses measured by the results questionnaire were good (B), and the achievement of critical thinking skills showed pretest scores of 4.93 and posttest scores of 7.32 in 30 students. Based on these findings it is known that the use of computer-assisted learning media for problem-based learning can stimulate students to think critically.

The strength of this research is the learning media was revised repeatedly. The strength of this research is that the learning media was revised repeatedly. The first revision was made after getting responses from substance experts and media experts. The second revision was done after getting input from teachers and colleagues. The third revision was carried out after students responded to learning in the limited trials. The fourth revision is done after students respond to learning media in the field trial. This repeated revision can create a perfect and useful learning media. Kumar (2011) who states the stages of experts assessment include: (1) make sure your skills are adequate with the proposed task; (2) accept the facts during the study; (3) look for evaluations from relevant supervisors or experts; and (4) do it yourself. Then, in the discussion of the results of the research, it is very valid because of the comparison of the findings points with other research /expert opinions. Furthermore, this study describes the advantages of computer-assisted learning media, namely: (1) students easily understand the material; (2) attract attention; (3) fun learning; and (4) improve students' critical thinking skills.

There are some weaknesses from the research of Kurniawati & Suryadarma (2015), there is no gap between expectations in the form of ideal learning /use of the desired media with the fact that learning /media use in the field is not ideal as a clear problem in the research background. This causes the research to be impressed by the willingness of researchers only not because of the demands of the learning problems that must be resolved. One of the functions of development research is solving a problem. This is supported by the opinion of Richey & Klein (2005) which states that development research has the function of making general conclusions, generating knowledge, and problem-solving functions. Then, in the technique of validating product assessment data, researchers should add media experts so that the data validity is more valid. This is because the proportion of media experts is very minimal when compared to colleagues and biology teachers. Furthermore, this study did not mention limited trial subjects. This raises doubts to the readers because limited trials should be conducted at schools that are equivalent to field trials and the number of subjects that are not much different. This is supported by the opinion of Sugiyono (2013) which states that trial subjects must consider: (1) research objectives; (2) representatives related to products; (3) the number of sample field trials is more than limited trials.

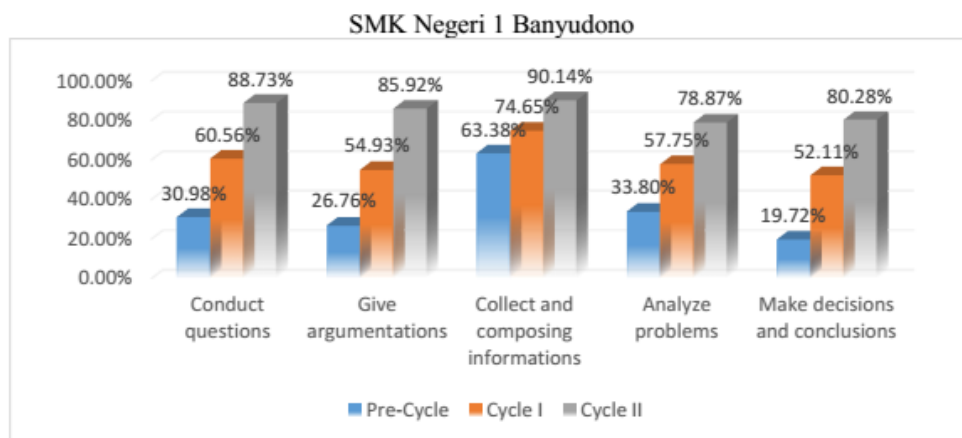
Research similar to the research of Kurniawati & Suryadarma (2015) is a study of Nirbita et al (2018). Nirbita et al. (2018) examined the application of media with information and communication technology to PBL on critical thinking skills. The purpose of this study is to improve critical thinking skills in accounting through information and communication technology media with PBL models. The media in this study are video-based banking problems. In the background, it has been explained the reality of students' low critical thinking skills, the urgency of research variables, and explaining the learning environment that is ideal for learning

improvement. The low data of students' critical thinking skills is indicated by statistical data from the Ministry of Education and Culture stating that education in Indonesia is still far from the same as only ranked 69 of 76 countries. This can be caused by several factors, one of which is 21st-century skills such as communication, collaboration, creative thinking and innovation, critical thinking and problem-solving. The urgency of this research is elaborated from several opinions, namely the opinion of Backman & Weber (2006), Eggend & Kauchak (2012), Santrock (2008).

For the presentation of the expectation points to complement the gap in this research, it is guided by the opinion of Meier (2005) and Lie (2010) which can be concluded that to improve the critical thinking skills of Indonesian students is to revolutionize teaching methods in the classroom. Teachers must use media, and act as motivators and facilitators when students learn actively in class. Interaction between fellow students or with the teacher, as well as an active and pleasant classroom atmosphere must be emphasized in learning. Then, it is continued with the elaboration of the theoretical foundation of several experts regarding the skills to think critically, and PBL with technology media and information as the solution.

This research is a class action research whose sample is determined by a cluster random sampling technique. The validity of the data uses triangulation methods with observation, interviews, documents, and source triangulation by involving class teachers, class X students, class XI students of SMK 1 Banyudono. The procedures of this study: (1) planning; (2) implementation; (3) observation; (4) reflection. The PBL implementation phase is assisted by information and communication technology media as follows: (1) the teacher explains the learning objectives; (2) random group distribution; (3) each group is given an ICT media in the form of a video containing an accounting problem; (4) students investigate other sources such as books, internet, etc .; (5) groups make power points to present solutions to problems; (6) the teacher explains and rectifies the problem and the solution; and (7) giving test results.

Based on analyzing the results and discussion of the study, critical thinking skills were assessed through observations of five aspects, namely the skills to ask, give arguments, collect and process information, analyze problems, and make decisions and conclusions. All aspects of critical thinking skills experience improvement from learning before cycle to cycle 1 and cycle 2. Data on critical thinking skills are presented in the presentation table for improvement in critical thinking skills. The percentage table increases students' critical thinking skills from this research as follows.



**Figure 1.** Percentage of improvements if students critical thinking skills in Nirbita et al (2018) research

Based on the percentage table of improvement in students' critical thinking skills, it appears that the aspect of analyzing the problem is the only one aspect that below 80% even though it has received treatment up to cycle 2, while the aspect of collecting and processing information is the highest increasing aspect achieve 90.14%. This is the strength of the research Nirbita et al. (2018) because by presenting clear data it will be easier for readers to analyze the findings of the research. Based on the results of the research and discussion, it can be concluded that the implementation of PBL assisted by information and communication technology media improves the critical thinking skills of students of SMK Negeri 1 Boyolali.

There are some weaknesses in Nirbita's research (2018), the first weakness lies in the background. In the background of this study, the main aspects of this study as variables Y (bound) or those that were influenced were not even explained. The researcher only explained the low quality of education in Indonesia by using one data from the Ministry of Education and Culture. As for critical thinking skills, there is no supporting data such as observation data, interviews, and data from research results conducted by other people. Then, there is no explanation of the risks that students will get if their critical thinking skills are low along with expert opinions that support the existence of these risks. This will cause a reduction in the level of validity of the study. This is in line with the opinion of Kumar (2011) and Richey & Klein (2005) which states that in scientific research, empirical data determine the validity of a study, as a comparison, and supporting conclusions, and inform better research practices.

In classroom action research studies do not require random sampling because this study is not representative of a population but only in one experimental class. According to Arikunto et al. (2012) which states that in class action research the sampling technique used is not probability sampling or sampling techniques that do not provide equal opportunities for each member of the population to be selected as a sample. Also, it can use purposive sampling, namely sampling techniques with certain considerations (Sugiyono, 2013).

Furthermore, in this study students' critical thinking abilities were assessed by observation only, while tests were carried out to assess the learning outcomes of students' cognitive aspects. The skills to think critically should be assessed by a description test especially the type of free description test. This is because the description test with open ended question has a deeper and broader level of assessment of the skills to think and associate student answers. This is supported by t Arifin (2017) who states that free description tests allow students to describe, organize, express, and express answers according to their abilities. In this study, measured critical thinking skills tended more to students' verbal abilities. This is detrimental to students with a visual learning style that tends to have difficulty expressing the contents of their mind that students with other learning styles. This is in line with the opinion of DePorter (2007) which states that students with visual learning styles have difficulty dialogue directly and are easier to express in written form.

According to Sanjaya (2012), multimedia can be divided into two there are linear multimedia and interactive multimedia. Isnaeny et al. (2018) examined the development of problem-based learning interactive multimedia to improve the critical thinking skills of students of the biology education study program at the University of Muhammadiyah Surakarta in learning materials on the human motion system. This study uses the development method of Borg & Gall (Moleong 2005) with 8 stages which include: (1) research and information gathering; (2) planning; (3) initial product development; (4) initial field test; (5) product revision 1; (6) limited field testing; (7) product revision 2; and (8) operational field testing. The background of this study is supported: (1) data from the analysis of 8 National Higher Education Standards in other studies stating that there are gaps/inefficiencies in the process of learning biology in Biology Education

at Muhammadiyah University in Surakarta; (2) observation data which shows that lecturers always teach by lecture method and students only listen, and (3) questionnaire results show that 93% of students answer lecturers more often to use media than modules or models. Then, this study outlines the importance of critical thinking skills by quoting the opinion of the Director-General of Higher Education & National Education Standards Agency (2014) and is guided by the results of interviews with lecturers.

The research method is described, including development procedures that are complemented by the Borg and Gall model flow. Then, the stages of product testing are explained in several stages, namely: (1) validation of material experts and model development experts; (2) group trials by lecturers and students; (3) field trials with quasi-experimental methods. Data collection of this study uses questionnaires, observation sheets, interview sheets and tests of critical thinking skills. Beside, this study presents a scoring system, level categories, and criteria for critical thinking skills in full. The results of the research and discussion at the research stage and initial data collection were carried out by syllabus analysis, completeness analysis of basic competencies, and indicators, analysis of the implementation of learning plans, classroom observations, media analysis which stated that 93% of students answered lecturers often using power points and 53% of they want more interactive multimedia, analysis of the skills to think critically in the midterm test and adventure questions at the end of the semester, analysis of the ideal PBL implementation. Then, in the initial product development phase PBL-based interactive multimedia Prototype books were produced and the characteristics of PBL-based interactive multimedia products.

At the earliest field testing stage showed that the validity of the media and material was categorized very well (A), and the validity of the device was classified as good (B). At the revision stage 1, there are improvements to the voice of the narrator, navigation, default volume, learning objectives and evaluation questions. Then in the limited field testing stage, material experts gave good (B) and very good (A) values, and from small group trials, the student questionnaire results showed that PBL-based interactive multimedia did not need revision because it was in a good category. So, in product revision 2 only navigation improvements were made. Furthermore, the results of statistical tests on critical thinking skills showed that PBL-based interactive multimedia succeeded in increasing students' critical thinking abilities by 28.4%, namely the average of the control class 57.7 and in the trial class 86.1. So it can be concluded if learning to apply PBL optimally with appropriate multimedia can improve students' critical thinking skills. The strength of this research is at the point of discussing the results of the study accompanied by expert opinions.

On the other hand, research by Isnaeny et al. (2018) has not described what risks will occur if students' critical thinking skills are low as a statement that reinforces gaps in the background. This was supported by Haviz (2013) who stated that good development research had problems, ideas, along with strong reasons. Furthermore, this study has not explained the expert opinions and its synthesis on each variable used. The theory is very important so that research has a basis in explaining the variables in the study. This is supported by Silverman (2005) who states that the theory in research is the provider of a series of explanatory concepts that should be understood from their relevance to the position of hypotheses, methods, and methodologies. Another weakness of this study is that there are no clear indicators of students' critical thinking skills. This confuses because of the many opinions of experts who put forward indicators of critical thinking skills and doubts about the results of the research that improves critical thinking skills can improve all aspects of critical thinking or only partially. This is supported by Kumar

(2011) who states that researchers must examine thoroughly, carefully, and critically and discuss the research problems in detail.

The animation is one type of multimedia that is often applied to the teaching and learning process. Munandar et al. (2018) examined the effect of PBL models assisted by animation media on critical thinking skills and physics learning outcomes. This type of research is quasi-experimental. Research methodology such as subjects, data collection techniques, instruments, data validity techniques, have been described. Based on the analysis of the initial test results, obtained the average value of critical thinking skills of the experimental class students is 39.08 and the average value of critical thinking skills of the control class students is 27.37 while the final test results of the analysis of students' critical thinking abilities indicate the average value of students in the experimental class is 65.28 and the average value of students in the control class is 51.29. Then, it can be concluded that there is an influence of PBL assisted by animation media on students' critical thinking skills in the form of increased skills in terms: (a) focusing questions, (b) analyzing arguments or reasoning, (c) inducing and considering induction results, (d) evaluating / assess the results of consideration, (e) provide reasons.

The weakness of Munandar et al. (2018) research is the same as Nirbita's research (2018) which has not explained the urgency of critical thinking skills in education, empirical data regarding the lack of critical thinking skills, and the gap between expectations and reality that the researchers intended in this study. This raises doubts such as the need for this research to be carried out even though there are no serious problems in the research aspect. Similar to the research of Isnaeny et al. (2018), this study only concluded that there was an effect of PBL models assisted by the animation on critical thinking skills with an average value of experimental and control classes without any further explanation per indicator of critical thinking skills. Even though the researchers mentioned indicators of critical thinking skills in the discussion of the results of the study. This is because only one or two indicators of critical thinking skills can increase, while there are indicators that are not affected by the animation-assisted PBL model.

As a comparison of the four studies above, it can be presented as a table as follows.



**Table 1.** Comparison methodology, advantages, disadvantages, and conclusion of studies

Comparison	Kurniawati and Suryadarma	Isnaeny et al.	Munandar et al.	Nirbita et al.
<b>Methodology</b>	Development research adapted from the ADDIE model.	Development research use Borg & Gall method with 8 stages.	This type of research is quasi-experimental.	A class action research
<b>Advantages</b>	<ol style="list-style-type: none"> <li>1. Followed by the explanation of the theory of PBL and computer-assisted learning media.</li> <li>2. The research stage and use of research instruments are described.</li> <li>3. The product evaluation data was carried out by many experts.</li> </ol>	<ol style="list-style-type: none"> <li>1. Background of study supported by official data, observation data, and questionnaire data.</li> <li>2. There is a gap in the study.</li> <li>3. Point of discussing the results of the study accompanied by experts opinions.</li> </ol>	<ol style="list-style-type: none"> <li>1. There are indicators of critical thinking skills.</li> <li>2. This study has a clear explanation of the comparison of the control class scores and the experimental class</li> </ol>	<ol style="list-style-type: none"> <li>1. There is an urgency and gap of study.</li> <li>2. There is an elaboration of the theoretical foundation of several experts</li> <li>3. Data on critical thinking skills are presented in the presentation table.</li> </ol>
<b>Disadvantages</b>	<ol style="list-style-type: none"> <li>1. There is no gap between expectations in the form of ideal learning /use of the desired media with the fact that learning/media use in the field is not ideal.</li> <li>2. The technique of validating product assessment data, researchers should add media experts so that the data validity is more valid.</li> </ol>	<ol style="list-style-type: none"> <li>1. This study has not described what risks will occur if students' critical thinking skills are low as a problem.</li> <li>2. This study has not explained the expert opinions and its synthesis on each variable used.</li> <li>3. There are no clear indicators of students' critical thinking skills.</li> </ol>	<p>Only concluded that there was an effect of PBL models assisted by the animation on critical thinking skills with an average value of experimental and control classes without any further explanation per indicator of critical thinking skills.</p>	<ol style="list-style-type: none"> <li>1. In the background of this study, there is no explanation of the risks and supporting data.</li> <li>2. Students 'critical thinking abilities were just assessed by observation only.</li> </ol>
<b>Conclusion</b>	The use of computer-assisted learning media for problem-based learning can stimulate students to think critically.	If learning to apply PBL optimally with appropriate multimedia can improve students' critical thinking skills.	There is an influence of PBL assisted by animation media on students' critical thinking skills in the form of increased skills.	The implementation of PBL assisted by information and communication technology media improves the critical thinking skills of students of SMK Negeri 1 Boyolali.

## CONCLUSION

Based on the discussion of research, it can be concluded that the use of feasible multimedia and optimal application PBL model can improve student's critical thinking skills. Based on studies by Kurniawati and Suryadarma (2015), Isnaeny et al. (2018), Munandar et al. (2018), and Nirbita et al. (2018), there are positive aspects that can be taken and weakness points as negative aspects that should be avoided by future researchers. Positive aspects of the above studies include: (1) the formulation of research objectives must obvious; (2) data in background must be using international research data and official data from national ministries, observations, questionnaires, and other research results; (3) research methods are explained in

detail; (4) the stages of implementation of the media are described; (5) research results data are presented with tables or graphs that are easy to understand; (6) discussion of research results must be accompanied by expert opinions; and (7) conclusion of the research must be accompanied by an explanation of the strengths and weaknesses of the media users based on the research that has been carried out with the intention of facilitating further research.

The limitation of this literature review research is that it only studies 4 studies with a multimedia-based on PBL theme. The types of multimedia studied were not yet diverse, only multimedia in the form of video, interactive multimedia applications, and animation. Though many types of multimedia are already widely used in education such as virtual reality, multimedia-based outdoor learning, etc. For further researchers, this research can be used as a reference theory and research methods that want to be used to study the application of multimedia-based on PBL. Also, it is hoped that there will be further studies on multimedia research based on PBL with multimedia that have never been studied before such as virtual reality.

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