



The Development of PBL Oriented E-Magazine to Improve Critical Thinking Skills and Caring Attitudes Laboratory Work Safety

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Article Info

Article History :
Received
February 2022
Accepted
May 2022
Published
August 2022

Keywords:

PBL, E-Magazine, Critical Thinking Skills, Caring Attitudes Laboratory Work Safety

Abstract

This research aims to test the validity and effectiveness of Problem Based Learning (PBL) oriented e-magazine teaching materials in improving critical thinking skills and caring attitude towards laboratory work safety. This research is a Research and Development (R&D) research that uses the ADDIE model by applying a pretest-posttest control group design. The subjects in this study were 51 students of class X MIA SMA N 7 Jambi City. Research instruments in the form of expert validation questionnaires, questionnaires on the readability of teaching materials, critical thinking skills test questions and attitudes about laboratory safety. The data analysis of the expert, practitioner, legibility, and practicality validation questionnaire data showed that the validity of the e-magazine was considered very valid. Effective teaching materials improve critical thinking skills seen from the posttest average of the experimental class is 80.1 and the control class is 71.3. The average N-gain of the experimental class is 0.59 (medium) and in the control class is 0.33 (medium). Effective teaching materials increase the attitude of caring for safety as seen from the posttest average of the experimental class of 79.6 and the control class of 74.7. The average N-gain of the experimental class is 0.55 (medium) and in the control class is 0.42 (medium). Based on the research results, PBL-oriented e-magazines are valid for use in learning and are effective in improving critical thinking skills and caring attitude towards laboratory safety.

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p-ISSN 2252-6412

e-ISSN 2502-4523

INTRODUCTION

Students in everyday life are often faced with complex science problems. These problems often cannot be solved by one discipline alone, but require the correlation of many disciplines. One effort that can be done is to direct students to have the ability to solve problems appropriately. Students must have an awareness of the need for a good understanding of concepts to solve problems so that they are able to develop strategies in solving problems. It is necessary to apply a learning model or approach that is oriented towards students (*student center*) in order to have the opportunity to construct knowledge, solve problems, and make decisions.

Problem Based Learning more emphasis on problem solving efforts through investigative activities. This research activity requires information from all sources. Information processing skills are one of the characteristics of critical thinking skills. Several previous studies have proven the effectiveness of the PBL learning model in improving students' critical thinking skills (Ningsih et al. 2018; Noer dan Gunowibowo, 2018; Satwika et al. 2018)

One of the educational facilities that serves as a support for the effectiveness of learning biology is a laboratory. The introduction of tools and procedures for using tools is very important in supporting work safety in the laboratory (Chen et al. 2020). Do not rule out the danger of accidents when learning in the laboratory. This can happen if students do not know how big the risk is due to a lack of understanding of safety in the laboratory. Based on news from *Jawa Pos Radar Solo* (2020) there was an explosion at the chemical laboratory of SMA Muhammadiyah 1 Surakarta. This accident occurred due to negligence of laboratory personnel while cleaning the magnesium liquid bottle and it was splashed with water. As a result, one laboratory worker suffered minor injuries. A work accident in a laboratory has also occurred at a secondary school in Bayan Lepas, based on the news of *Rakyatku.com* (2019) as many as 20 students suffered from shortness of breath and coughing after a chemical leak occurred. Based on the news, it is very possible for an accident to occur if students do not understand how to handle tools and materials properly.

Based on interviews with the biology teacher at SMA N 7 Jambi City, information was obtained (1) learning resources only came from printed books and worksheets prepared by the school, (2) less active students in class (3) the average knowledge of students about laboratory safety material is classified as low 61.86% (Trisna et al. 2021) (4) explanation of material on laboratory work safety in student handbooks is not complete, (5) there have been several accidents in the laboratory such as (a) broken glass instruments such as test tubes, measuring cups, glass objects and petri dishes, (b) microscopes that are moldy due to improper storage methods, (c) improper practicum methods such as heating substances that are too close to the heating source so that the test tube breaks and the substance overflows, and (d) irritation to the skin of the students' hands due to 96% alcohol exposure. This is a problem that cannot be ignored because knowledge of laboratory work safety is a basic knowledge that must be mastered by students in order to work correctly and safely in the laboratory.

Problems in learning biology, especially in the scope of biology, it is necessary to make efforts to improve the quality of learning. One solution is the development of an electronic magazine that can meet the needs of students and can improve critical thinking skills and an attitude of caring for work safety in the laboratory. PBL - oriented e-magazines have several advantages, including (1) can provide a problem-oriented learning experience so that it can solve problems (2) the existence of discussion forums can encourage students to have opinions so that they are trained to criticize other people's opinions, (3) with a learning environment *online* allows students to explore information from various sources, and (4) can be used as a companion book in independent study at home and at school.

METHODS

This research is a type of research and development (R&D) using the ADDIE model (Analysis, Design, Development, Implementation and Evaluation). The research subjects consist of one material expert lecturer, one media expert lecturer, four practitioners (biology teacher) and 51 students class X MIA SMAN 7 Jambi City. The research instrument used is a questionnaire, critical

thinking ability test questions and attitudes about laboratory safety. Aspects of critical thinking skills (Ennis, 2018) include (1) providing simple explanations, (2) building basic skills, (3) conclude, (4) provide further explanation, and (5) strategy and tactics. The first stage of the research is a field analysis. In the field analysis stage, interviews were conducted with four biology teachers to identify problems that occur in learning biology. The second stage consists of designing teaching materials that are developed and designing learning tools such as syllabus, lesson plans, and test questions. The third stage is the development stage, the process of realizing the concept into a product that is ready to be implemented. In addition, product validation and revision are also carried out to achieve the expected goals. The stage of developing teaching materials in this research includes the expert validation stage, the limited trial stage and the test-test instrument stage. The fourth stage is the implementation of PBL-oriented e-magazine. The e-magazine trial design used the *Pretest-Prosttest Control Group Design* model. At this stage, a test of critical thinking skills and an attitude of caring for laboratory work safety is carried out at the beginning and end of learning. The

fifth stage is evaluation which aims to evaluate the validity and effectiveness of the developed teaching materials.

Validity analysis using descriptive quantitative. Based on validation by the validator, PBL - oriented e-magazine teaching materials can be said to be valid for use in the learning process if an assessment score $>62.5\%$ is obtained. The effectiveness of teaching materials obtained from *pretest* and *posttest*. Data analysis was used to determine the effectiveness of teaching materials using the N-gain test. Categorized in the normalized gain criteria (Aryani dan Mansur, 2017) $G > 0.70$ (high); $0.30 < G < 0.70$ (medium); and $G < 0.30$ (low).

RESULT AND DISCUSSION

Validity of E-Magazine

The validity of the e-magazine was obtained from the validation of experts, practitioners, legibility and practicality. The experts were chosen by two expert lecturers consisting of biologists, media experts, practitioners and students of class X MIA SMA N 7 Jambi City (Table 1).

Table 1. E-magazine validation

Validation	Evaluation	Percentage	Category
Material experts and practitioners	Content	88.6	Very good
	Presentation	90.5	Very good
	Language	86.0	Very good
	PBL	98.3	Very good
Average		90.8	Very good
Media experts and practitioners	Teaching material format	100	Very good
	Cover design	97.5	Very good
	Content design	93.3	Very good
Average		96.9	Very good
Legability	Content	87.0	Very good
	Language	89.0	Very good
	Presentation	93.0	Very good
Average		89.6	Very good
Practicality	Learning	89.0	Very good
	Simplicity	87.9	Very good
Average		88.5	Very good

Table 1 describes the acquisition of teaching material validation scores by the validator. The average percentage score given by the material validator is 90.8% with a very valid category. This is

because all the component items have been fulfilled and complete. The content of the material presented is adjusted to the basic competencies and learning objectives. The structure of the teaching materials

used was adopted from Yulianto dan Rohaeti (2013), which consists of *a front cover* containing the title of the magazine and the topics to be discussed, a content page containing subject matter starting with apperception and a brief description as the basis of knowledge as well as case studies to be discussed. presented in accordance with basic competencies, and *the back cover* which contains a synopsis of the contents of the magazine.

The highest rating is in the PBL aspect which gets a percentage of 98.3% (very good category). This is because e-magazines *are* compiled based on PBL learning steps by adapting cases or the reality of events that have occurred, so that students are able to relate learning to the realities of life around students. Studies of cases contained in the e-magazine is useful to invite the participant students identify and provide solutions on issues. Some aspects of the assessment of the PBL component include conformity to the nature of PBL and orientation to problems.

The language aspect gets a percentage of 86.0% (very good category) although if viewed from several other indicators the language aspect is the lowest, but the category on this indicator is still very well used. Based on the assessment of the validator, it is known that the value obtained from each aspect ranges from 3 to 4. This is possible because according to the validator the *e-magazine is* less communicative and in accordance with the development of students. According to Darancik (2018), the use of communicative vocabulary and grammar can improve students' understanding of the meaning of the material. However, the language aspect of the e-magazine is in accordance with the provisions set by the BSNP, namely using communicative language, easy to understand, and does not cause multiple interpretations, making it easier for students to understand the content of teaching materials . The assessment aspects of the language in the e-magazine covering conformity with the level of development thinking participant learner, communicative, candor, interactive, and conformity with the rules of Languages Indonesia. Wicaksono (2016) states that language is used as a communication tool to achieve the desired goal. In general, there are several suggestions given by the material validator, namely that there is a writing error in the biology role. In addition, the use of

images in teaching materials that are possible can be taken directly and some images are quoted from the internet by including the source.

The average percentage score of the media validity of e-magazine teaching materials is 96.9% with very good criteria. This is because in general all validators give a very good assessment of each component item, which means that the media aspects contained in the e-magazine have been fulfilled. Media teaching materials e-magazine has a front cover display that contains the title of the magazine, images, university logos, and authors. In addition, on the front cover page there is also some interesting content contained in the contents of the magazine as an overview of the contents of the magazine. It aims to attract the interest of readers and increase the reader's curiosity about the magazine. The back cover is designed to be simpler by containing a synopsis of the contents of the magazine.

The highest assessment of teaching material media is the aspect of the format of teaching materials which gets a percentage of 100% in the very good category by experts and practitioners. The format of the e-magazine teaching materials is categorized as very good because these aspects have met the criteria, namely the size of teaching materials that have met ISO standards , cover design and attractive appearance, use of the right type and size of letters, photos and images displayed clearly and in accordance with the material that is presented, systematics within the material of teaching the right, and the supporting presentation materials teaching full. The first impression of a magazine for readers is the cover. The cover of an e-magazine or book has an important role as a protector of the content as well as being a part that attracts the interest of the reader. Gumono (2016) argues that to make a book popular so that it is interesting to read, the appearance of the book is made more attractive, the content tends to be varied accompanied by pictures, text that is not monotonous and is equipped with colors that reinforce the message.

The use of color in the e-magazine uses bright colors so that it can motivate students to see and read it. One component that attracts the reader's attention in a teaching material is a picture or illustration. The use of images in the e-magazine

partly comes from the internet (mentioned source/link) and some images come from personal documentation to avoid plagiarism. In accordance with Arsanti (2018), the existence of images makes the material shorter, clearer, focused, and interesting. Images give the magazine a more attractive physical appearance so that it can attract readers' interest. The use of color images can improve students' memory of the materials and images used (Khan & Liu, 2020).

The content design aspect received a percentage of 93% (very good category). Although this indicator scores lower than the others, this indicator is still in the very good category. This is possible because according to the validator the correlation between the background and the typeface used in the e-magazine is not good and is not easy to read. This is in line with the opinion of Negara et al. (2019) that the attractiveness of a module for students can be seen from the way the message is delivered (in the form of pictures or writing) and content that is in accordance with the times. However, the e-magazine *is* very well designed, taking into account the print area and proportional margins, the spacing between text and images is appropriate, the letters used in teaching materials are of the right size, not too many types of letters are used and the use of letter variations is not excessive. The content design in teaching materials is equipped with material titles, material subtitles, and there are pictures and case studies that strengthen the material. In general there are several suggestions or comments provided by the validator that there is a typing error in the preface that are less suitable as a title to be replaced with a "Preface", layout errors in the diagram objects biology, provision of source images which quoted from the internet.

The average percentage of readability scores is 89.6% with the readability criteria "very good". This shows that the e-magazine *is* easy to understand and can be used as a learning resource related to the scope of biology. Based on the results of the analysis of the readability of teaching materials, the percentage of the "presentation" aspect is the highest percentage of the assessment. It is known that 93% of students stated that the type, font size, background color and images made the e-magazine interesting. This is in accordance with Citraningrum

(2016), that pictures or illustrations provide variations on teaching materials so that they become more interesting and make it easier for readers to understand the message. Overall the assessment on the presentation aspect is very good, as for the comments on the e-magazine that there are still some writings that are difficult to read because the background uses dark colors.

Based on the analysis of the readability assessment of teaching materials, it is known that the lowest percentage in the aspect of "material content" in the e-magazine is 87% (very good). According to students, the material presented is adequate for independent study and the case examples presented are examples of real problems so that they guide students to find material concepts. Overall, the assessment on the "content" aspect is very good, but suggestions from students are that the material presented is made more concise so that it does not have many pages.

The average percentage of practicality of PBL - oriented e-magazine teaching materials is 88.5% and is in the very good category. The learning aspect got a percentage of 89.0% (very good). The score shows that students feel that using e-magazines can add insight into the scope of biology and help guide students to solve a problem. The case studies presented in the e-magazine stimulate students to think critically to find solutions to the problems they face by reviewing the literature as information and group discussions. Aisyah et al., (2020) stated that the use of appropriate teaching materials will make the role of students become more dominant in the learning process.

The ease aspect gets a percentage of 87.9% (very good), because it is easy to use anytime and anywhere. In addition, according to students, the material presented uses simple, concise, clear, and effective sentences and language, making it easier to understand the contents. The use of good and correct language is one of the efforts to make it easier for students to understand what is being learned (Hadi et al., 2018). The results of this study are supported by Suniasih (2019) that practicality refers to the ease with which students use textbooks in accordance with the allocation of time, tools and materials, as well as media that are easy to obtain and use.

Critical Thinking Ability

The results of increasing critical thinking skills were obtained from the pretest and posttest scores, then analyzed using the N-gain test to find

out how much the students' critical thinking skills increased after attending the lesson. The results of increasing critical thinking skills are presented in Table 2.

Table 2. Results of critical thinking skills

Aspect	Criteria	Experiment		Control	
		F	%	F	%
N-gain	High	4	15.4	1	4.00
	Medium	22	84.6	14	56.00
	Low	0	0.00	10	40.00
Pretest		48.2		48.5	
Posttest		80.1		71.3	
Average N-gain		0.59		0.33	
Category		Medium		Medium	

The average *posttest* value of the experimental class was 80.1 and the control class was 71.3. The results of the t-test to see the difference in learning outcomes of the two classes obtained a significance value of 0.00 where the value is <0.05 , it can be concluded that there are differences in learning outcomes between the control and experimental classes. The results of the N-gain calculation for the experimental class and control class are in moderate criteria. The average increase in the value of the experimental class is 0.59 and in the control class is 0.33. Based on the learning outcomes and the N-gain value, it was concluded that the experimental class was better than the control class.

In general, the two classes experienced an increase in critical thinking skills, the difference in increasing critical thinking skills was influenced by the implementation of e-magazine. Learning using PBL-oriented e-magazines provides many opportunities for students to solve problems presented through case studies, collect information through literature studies and answer questions presented so that they can change students' mindsets to become more critical of problems. This is in accordance with the research of Vong dan Kaewurai (2017) that the key to critical thinking skills lies in the process of identifying problems, investigating data, discussing findings, evaluating findings, creating solutions, presenting solutions, and reflecting on learning outcomes.

Learning activities in the experimental class are carried out based on the PBL syntax. To solve problems, students are asked to collect information

related to learning materials and process this information so as to stimulate participants to interpret the problem more deeply, not just memorize it. This is in accordance with the opinion of Magdalena *et al.* (2020) that increasing critical thinking skills can be seen from the critical evaluation of students about the validity of facts so that they do not only receive information from the teacher. In today's technological era, it is very easy to get answer information to solve problems, but students must have a basic knowledge to filter any information obtained. In line with Wayudi dan Santoso (2020) so that the information obtained by a person can be useful and does not cause a negative impact, a "*filter*" is needed to filter any information received. The results of this study are in accordance with Saputro *et al.* (2020) that learning with the PBL model can effectively improve critical thinking skills.

The critical thinking ability of the control class has also increased, due to the handbook and the application of the "*group investigation*" learning model that facilitates students to be actively involved in learning. Learning begins with the distribution of group members and discussion topics, material exploration and discussion, and ends with evaluating learning. Learning in the control class provides opportunities for students to be able to explore material from various sources in groups and analyze the topic. This analysis process can improve students' critical thinking skills. This is in line with the research of Damayanti *et al.* (2020) that there is an increase in critical thinking skills using the *group*

investigation type cooperative learning model because the analysis process in the shared learning topics, through this analysis process can improve students' critical thinking skills.

Based on the critical thinking ability *test* grid, it can be analyzed the achievement of critical thinking skills on indicator (Table 3).

Table 3. Criteria for N-gain indicators of critical thinking skills

Indicator	Group	Category			Average N-gain
		Low	Medium	High	
Simple explanation	Control	6	13	6	0.56
	Experiment	7	10	9	0.64
Building basic skills	Control	10	11	4	0.53
	Experiment	5	10	11	0.90
Conclusion	Control	5	15	5	0.31
	Experiment	3	18	5	0.61
Further explanation	Control	9	11	5	0.39
	Experiment	6	13	7	0.62
Strategy and tactics	Control	10	12	3	0.39
	Experiment	4	13	9	0.56

Based on the value of N-gain, it can be analyzed the achievement of students' critical thinking levels on each indicator (Table 3). The number of students in the medium-high category on the "conclusions" indicator was 20 people in the control class and 23 people in the experimental class. This number is the highest compared to other indicators. This is because in the experimental class there are digital literacy activities in the process of finding sources of information so that students are trained to make conclusions. The ability to conclude in the experimental class is also obtained after students understand the cases that occur either through the process of seeking information or exchanging opinions among group members. While in the control there is an activity to review learning and ends with drawing conclusions. According to Shutaleva *et al.* (2021) the ability to process information obtained from the internet proves the existence of a person's critical thinking ability. Students perform analysis and evaluation of every possible answer found to draw conclusions.

The indicator that has the highest N-gain value in the experimental class is building basic skills (0.90). This is due to the investigation activities in the PBL model. Through investigation activities on a problem, students are trained to find information related to the problem, consider the suitability of the sources used, report findings, and account for the

results of the investigation. This is in accordance with (Rahmadani, 2019) that the investigation provides an opportunity for each group to conduct an investigation by conducting a study of various reference books and providing opportunities for students to argue to solve problems.

The indicator of critical thinking skills in the control class that gets the highest *gain* value is to provide a simple explanation, this is because the "*group investigation*" learning model directs students to study independently before learning is carried out in class, students are divided into several groups to understand the sub-materials covered. different and take note of the important things. When learning occurs in class, students conceptually have mastered the material to be studied. This is in accordance with Wahyuni *et al.* (2018) that the *group investigation* stage instructs students to study the material before learning begins so that they can practice aspects of giving simple explanations.

Safety Care Attitude

The results of increasing safety care attitude were obtained from the pretest and posttest scores, then analyzed using the N-gain test. The N-gain calculation *is* used to find out how much the increase in the attitude of caring for the safety of students after taking part in learning.

Table 4. Results of the attitude of caring for safety

Aspect	Criteria	Experiment		Control	
		F	%	F	%
N-gain	High	10	38.46	0	0.00
	Medium	12	50.00	18	72.00
	Low	4	11.54	7	28.00
Pretest		51.0		49.6	
Posttest		79.6		74.7	
Average N-gain		0.55		0.42	
Category		Medium		Medium	

The average *posttest* value of the experimental class was 79.6 and the control class was 74.7. The results of the t-test to see the difference in learning outcomes of the two classes obtained a significance value of 0.03 where the value is <0.05 , it can be concluded that there are differences in learning outcomes between the control and experimental classes. The results of the N-gain calculation for the experimental class and control class are in moderate criteria. The average increase in the value of the experimental class is 0.55 and that of the control class is 0.42. Based on the learning outcomes and the N-gain value, it was concluded that the experimental class was better than the control class.

The difference in attitude values is because in the experimental class students get problem-based learning through e-magazines in the form of case studies. Learning by utilizing case studies in e-magazines invites students to be able to analyze the causes of an accident and how to overcome it. This is supported by Badarudin (2018), that learning using PBL can improve the development of students' conceptions as well as efforts to develop and shape attitudes. Students with good knowledge of work safety will know the risks that can occur if they ignore it. Students' adherence to the safety of using tools and materials in the laboratory can reduce the risk of accidents (Salazar-Escoboza *et al.*, 2020). With sufficient knowledge of safety procedures in the laboratory, students can anticipate and deal with

accidents. The e-magazine used contains materials about working with laboratories such as how to use tools, how to handle tools, rules for working in the laboratory, and accidents occurring in the laboratory and their handling.

The increase in the attitude of caring for laboratory work safety in the control class is due to the handbook that is equipped with material concepts about the rules of working in the laboratory, so that students know the concept of work safety in the laboratory. This is in line with the research of Tarawi *et al.* (2020) that awareness of work safety can be grown through knowledge. The "*group investigation*" learning model applied to the control class directs students to actively seek material independently. After students conduct an investigation looking for information about the subject, students gain an understanding of how to maintain work safety in the laboratory. This is in accordance with the opinion of Dantjie (2016), that learning related to effective laboratory work safety is in line with being applied to an active role in recognizing potential hazards, assessing risks and being able to anticipate work accidents in the laboratory.

Based on the safety care attitude test, it can be analyzed the achievement of the students' safety care attitude level on each indicator. The level of achievement of each indicator in the study from both the experimental and control classes is presented in Table 5.

Table 5. Criteria for N-gain indicators of the attitude of caring for laboratory safety

Indicator	Group	Category			Average N-gain
		Low	Medium	High	
Job protection	Control	12	10	3	0.36
	Experiment	6	10	10	0.52
Sewage system	Control	6	12	7	0.53
	Experiment	6	15	5	0.53
Equipment for prevention and relief	Control	7	11	7	0.48
	Experiment	4	14	8	0.59

Based on the N-gain value, it can be analyzed the achievement of the level of safety care attitude in each indicator (Tabel 5). The number of students in the medium-high category on the "prevention and rescue equipment" indicator was 18 people in the control class and 22 people in the experimental class. This number is the highest compared to other indicators. This is because the learning process has taught students about prevention and aid tools, for example what to do in an accident, what tools to use when an accident occurs, what to do to avoid an accident. In this section, students are encouraged to be able to explain, evaluate and analyze prevention and aid tools.

The indicator that has the highest N-gain value in the experimental class is the equipment for rescue prevention devices (0.59). The increase in the ability to care about safety in this indicator is caused by the PBL step, namely conducting investigations and evaluating. Through investigation activities on a problem, students are trained to find information related to the problem, consider the suitability of the sources used, report findings, and account for the results of the investigation. This is in accordance with Mathilda (2019) that investigations are carried out to find solutions to problems by analyzing and defining problems, developing hypotheses, collecting and analyzing information, conducting experiments (if needed), making inferences, and formulating conclusions. The case studies presented in the e-magazine talk about accidents that have occurred so that students can learn and analyze what the causes are, how to prevent them and how to solve them if these incidents occur in the environment. Laboratory safety and security is a shared responsibility of both managers and users, therefore everyone involved must have awareness and feel called to regulate, maintain, and strive for

work safety (Sangi *et al.*, 2018). In the experimental class, students are taught how to help due to accidents such as poisoning, fire, and injuries caused by hazardous substances.

The indicator that has the highest N-gain value in the control class that gets the highest *gain* value is the waste disposal system (0.51). Students have been able to analyze laboratory waste and know the steps for managing laboratory waste properly. The application of the *group investigation* model makes students actively involved since planning, both in determining topics and how to obtain information. Group investigations emphasize the participation and activities of students to find their own learning material (informants) to be studied through available materials, for example from textbooks and the internet (Parinduri *et al.* 2017).

CONCLUSION

Based on the results and discussion of the research, it can be concluded that the PBL - oriented e-magazine teaching materials are very valid to be used in Biology learning. *The* resulting e-magazine is also effective in improving critical thinking skills and caring attitude towards laboratory safety.

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