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Development of Interactive Multimedia Based on Problem-Based Learning to Improve Learning Outcomes of Light Properties Material

Selviana*, Aldina Eka Andriani

Elementary School Teacher Education, Faculty of Education and Psychology, Universitas Negeri Semarang, Semarang, Indonesia
*e-mail: selvieana15@students.unnes.ac.id

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Abstract: The use of technology in science learning media is not optimal, causing low learning outcomes for students. This study aimed to develop a design and test the feasibility and effectiveness of interactive multimedia based on Problem-Based Learning to improve the learning outcomes of fifth-grade students of SDN Pesantren Semarang City. The type of research is Research and Development (R&D) using the Borg and Gall model. The research subjects were 26 fifth-grade students of SDN Pesantren. Data collection techniques using non-test techniques (observation, interviews, questionnaires, and documentation) and test techniques (pre-test and post-test). Data analysis techniques used normality test, t-test, and N-Gain test. The results showed that the design of Problem-Based Learning-based interactive multimedia development using the Canva application contains the main page, main menu, instructions for use, concept map, Problem-Based Learning-based learning materials, virtual laboratories (Dynamic Labs), learning videos, interactive quizzes (Genially), and developer profiles; the feasibility of Problem-Based Learning-based interactive multimedia from material experts 93.75% very feasible criteria and media experts 92.18% very feasible criteria. The results of the teacher response questionnaire are 100% very feasible criteria and 96.80% student response with very feasible criteria; the effectiveness of interactive multimedia based on Problem-Based Learning is shown from the increase in pre-test and post-test scores by 33.65, paired sample t-test results show the significance value (2-tailed) is <0.001 which based on the criteria the value is below 0.05, and the N-gain test results are 0.6913 medium criteria. This study concludes that interactive multimedia based on Problem-Based Learning was successfully developed, very feasible, and effective in improving the learning outcomes of the properties of light material for fifth-grade students of SDN Pesantren Semarang City.

Keywords: Interactive Multimedia; Learning Outcomes; Problem-Based Learning; Properties of Light.

Introduction

Education is an endeavor undertaken to improve a person's quality of life. Education in Indonesia is closely related to learning theories, including constructivism. Constructivism is a theory that discusses how learners build knowledge based on the different experiences of each person [1]. National education standards in Indonesia are regulated in Government Regulation (PP) Number 4 of 2022, explaining the competency standards of graduates in education units at the essential education level focus on forming students who are faithful, pious, noble, have character according to the values of Pancasila, and have literacy and numeracy competencies [2]. The current curriculum in Indonesia is the Merdeka Curriculum. The Merdeka Curriculum combines science and social studies subjects into Natural and Social Sciences at the basic education level. The purpose of combining Natural and Social Science subjects is to encourage students to maintain and preserve the natural and social environment in one unit [3].

Learning is a process carried out by learners to acquire new knowledge. Learning is an effort the teacher makes to encourage students to achieve competence per the curriculum [4]. Natural science learning involves several aspects: product, process, attitude, and application/technology. Natural science learning is expected to be ideal. Ideal learning can make students active, creative, and fun to achieve learning goals [5]. The activeness and creativity of learners can be encouraged through variations in the stimulus provided by the teacher, variations in learning activities such as discussions, questions and answers, and practicum activities, as well as variations in learning media to facilitate learners' learning styles. Learning can be fun with games such as interactive quizzes. With ideal science, learning conditions will deepen understanding and improve student learning outcomes, so that learning objectives can be achieved.

Based on pre-research data obtained through observation, interviews, questionnaires, and documentation conducted with fifth-grade teachers and fifth-grade students of SDN Pesantren Semarang City, it shows that teachers have not been optimal in using technology-based learning media; this is because the learning media used is not interactive. The teacher has not varied the stimulus in using PowerPoint, and there is no description of each phase of the learning model in the learning media used. This is evidenced by students who feel bored and lose concentration in the learning process, such as students who put their heads on the table when it occurs. Variations are

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needed in learning activities so students are not bored following the learning process [6]. The utilization of technology in learning has not been maximized due to the mastery of technological literacy, which still needs to be improved [7].

Teachers have not been optimal in applying the Problem-Based Learning model because the implementation of syntax 1, 2, and 3 has not been maximized. The stimulus provided in Syntax 1 does not vary because the teacher only uses questions and pictures. Teachers who do not make variations cause students to become bored and less interested in participating in learning, thus causing learning objectives not to be achieved [8]. In Syntax 2, the teacher divides students based on their level of understanding, but the teacher does not immediately arrange the seating position of students according to their level of understanding. The teacher should immediately organize the position of the students' seats. The teacher divides the learners into groups and arranges the learners' seating positions in an organized manner [9]. In Syntax 3, the teacher provides e-worksheet and makes e-worksheet like a problem; e-worksheet should be distributed in Syntax 2 after students have arranged their sitting positions. In syntax 2, namely organizing students, the teacher forms students into several groups, distributes e-worksheet to each group, explains how to work on e-worksheet, and students work on e-worksheet [10]. So, the nature of problem-solving has not yet emerged in the learning process.

The learning outcomes of students on the properties of light are still low. Learning outcomes are the results students obtain after participating in learning [11]. Students are less interested and less focused on science learning because they think the material on the properties of light is challenging to understand. After all, it is abstract [12]. This is indicated by the results of the cognitive diagnostic assessment of light's properties; 77% of students are still below the criteria for achieving learning objectives *(KKTP)*. At SDN Pesantren, the assigned *KKTP* is 80. This research shows that 23% of students meet *KKTP*, and 77% do not meet *KKTP*. One of the factors that cause low learning outcomes is the lack of innovation in using learning media [13].

Students' understanding of the properties of light is still lacking because students have difficulty understanding foreign terms that are less familiar in everyday life, such as the terms “refracted” and “decomposed”. Students experience misconceptions about distinguishing the properties of light, namely that light can be refracted and decomposed. Misconceptions that occur to students in the learning process are one of the factors that cause learning objectives not to be achieved [14]. In addition, the material of the properties of light is one of the materials that is difficult for students to understand; this is because students find it challenging to describe the properties of light, which requires students to think abstractly. In science, learning contains abstract concepts, so it requires a deep understanding obtained from direct experience [15].

Based on the above problems, improving the learning process using technology-based learning media, namely interactive multimedia based on Problem-Based Learning, is necessary. The combination of several media, such as text, sound, images, video, and animation, is called interactive multimedia [16]. The advantage of interactive multimedia is that students can learn the material in various ways [17]. Interactive multimedia helps teachers convey abstract material so that students can understand the material well [18]. In addition, interactive multimedia is practical because it can be used repeatedly [19]. The use of interactive multimedia can deepen students' understanding of learning materials, which has an impact on improving the learning outcomes obtained. Applying interactive multimedia in science learning can enhance learning outcomes and student motivation [20].

Interactive multimedia combined with Problem-Based Learning. Problem-based learning is a learning model that begins with a problem, with the problem encouraging students to collaborate to determine solutions and solve problems [21]. Problem-based learning can train students to think critically and deftly when solving problems [22]. Researchers developed interactive multimedia based on Problem-Based Learning using the Canva application equipped with a virtual laboratory (Dynamic Labs) as a variety of stimuli and preparation before direct practicum, as well as interactive quizzes from Genially to create fun learning.

Previous research on interactive multimedia based on the Problem-Based Learning model concluded that the interactive multimedia learning media developed was valid, practical, and effective [23]. Other research that discusses interactive multimedia in science subjects concludes that science learning media based on various kinds of forces using Adobe Flash is feasible and well applied in elementary schools [6].

Based on previous research that discusses interactive multimedia with the conclusion that interactive multimedia by utilizing Adobe Flash is very feasible and well applied in elementary schools [6]. Researchers developed interactive multimedia on the properties of light with novelty, namely using the Canva application, applying the Problem-Based Learning model in interactive multimedia, compiling and designing their learning videos, equipped with virtual laboratories (Dynamic Labs), and interactive quizzes from Genially. Researchers developed interactive multimedia based on Problem-Based Learning to improve the learning outcomes of fifth-grade students of SDN Pesantren Semarang City regarding the properties of light material. This study aimed to develop a design and test the feasibility and effectiveness of interactive multimedia based on Problem-Based Learning to improve the learning outcomes of the properties of light material for fifth-grade students of SDN Pesantren Semarang City.

Research Methods

This type of research is Research and Development using the Borg and Gall development model. The research and development step consists of 10 steps, namely: 1) potential and problems, 2) data collection, 3) product design, 4) design validation, 5) design revision, 6) product trial, 7) product revision, 8) usage trial, 9) product revision, 10) mass production [24]. In this study, it was impossible to carry out stages 9 and 10 because the researchers had limitations. Researchers have limited time and limited costs.

The sample of this study was fifth-grade students of SDN Pesantren, totalling 26 students, with 13 male students and 13 female students. Data collection techniques comprised tests (pre-test and post-test) and non-tests (observation, interviews, questionnaires, and documentation). Data analysis techniques were used to test the effectiveness of interactive multimedia based on Problem-based Learning using normality tests, t-tests, and N-Gain tests.

Results and Discussion

This research focuses on developing the design, feasibility, and effectiveness of interactive multimedia based on Problem-based Learning about the properties of light.

Development of Interactive Multimedia Design Based on Problem-Based Learning

This research is a research and development using the model from Borg and Gall and up to stage 8, namely:

Potential and Problems

Researchers conducted pre-research at SDN Pesantren. The results of the pre-research show that at SDN Pesantren, there are problems in the science learning process; namely, teachers have not been optimal in utilizing technology-based learning media, so students' learning outcomes are low. This can be seen from the cognitive diagnostic assessment of the properties of light material, which shows that 77% of students have not yet reached the criteria for achieving learning objectives *(KKTP)*.

The potential of SDN Pesantren is that it has pretty complete facilities. The facilities at SDN Pesantren support the learning process, and there are projectors, loudspeakers, and *WiFi* in every classroom.

Data Collection

Researchers distributed needs questionnaires to fifth-grade teachers and fifth-grade students of SDN Pesantren. The teacher needs questionnaire analysis results show that teachers need interactive multimedia learning media based on problem-based learning regarding the properties of light. Teachers agree with interactive multimedia as a form of teaching media development [25].

Based on the questionnaire analysis of the needs of students, it shows that students feel that the material of the properties of light is challenging to understand and the learning outcomes of cognitive aspects on the material of the properties of light need to be improved. Learners need technology-based learning media that can facilitate students' learning style, namely interactive multimedia, with bright color criteria, instructions for use, and virtual laboratories, and students choose the Problem-Based Learning learning model to be applied in interactive multimedia.

Product Design

Researchers design products according to the teacher and learner needs and use questionnaire results. Interactive multimedia based on Problem-based Learning is based on the results of the questionnaire analysis of the needs of teachers and students. The researcher designed the product using the *Canva* application containing the main page, main menu, instructions for use, concept map, Problem-Based Learning-based learning materials, virtual laboratories *(Dynamic Labs)*, learning videos, *Genially* interactive quizzes, and developer profiles. Interactive multimedia based on Problem-Based Learning facilitates students to improve learning outcomes with the presence of materials, learning videos, and laboratories as a place for students to deepen their understanding of the properties of light, as well as interactive quizzes from the *Genially* application that can be used to measure the level of understanding and learning outcomes of students.

The advantages of interactive multimedia based on Problem-Based Learning are that syntax one has various stimuli; the first learning uses pictures, and the second learning uses videos. Syntax 2 is present based on cognitive diagnostic assessment, namely grouping students based on the level of understanding, including very advanced, advanced, and need guidance. E-worksheet has been distributed directly to students. In Syntax 3, students received e-worksheet and started to solve problems with it. Researchers use bright colors and images suitable for elementary school students to make them attractive to students. Researchers make learning videos by designing and compiling videos and then incorporating them into learning media. A virtual laboratory (Dynamic Labs) contains a simple practicum on the material of the properties of light as a solution to the absence of a laboratory at SDN Pesantren and as a stimulus for students before doing the practicum directly. The presence of a virtual laboratory can be a solution to a practicum that is difficult to do because of the lack of practicum tools in conventional laboratories [26]. Interactive multimedia based on Problem-based Learning includes an interactive quiz from the Genially application that interests students.

Figure 1. Main Page

Figure 2. Instructions for using page

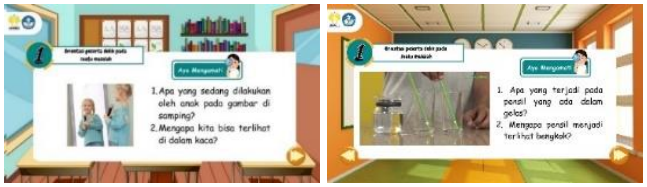

Figure 3. Syntax 1

Figure 4. Syntax 2

Figure 5. Syntax 3

Figure 6. Syntax 4

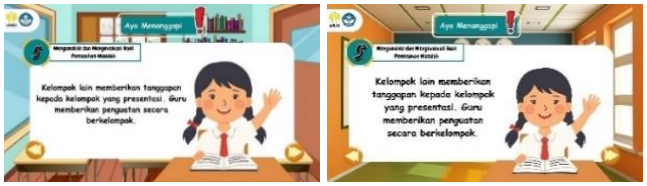

Figure 7. Syntax 5

Figure 8. Learning video

Figure 9. Virtual Laboratory (Dynamic Labs)

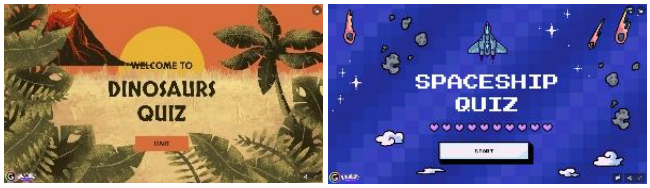

Figure 10. Interactive Quiz (Genially)

Design Validation

Design validation was carried out by testing the validity of material and media experts. Researchers made a validation questionnaire for material experts and media experts. Researchers gave validation questionnaires to material and media experts. Then, the results of the material and media expert questionnaires were analyzed to determine whether or not the product was feasible to apply in learning activities. The results of material and media expert validation obtained very feasible criteria. Material and media experts suggest placing the previous and next buttons higher to make them easier to access and adding *e-worksheet* links to interactive multimedia.

Design Revision

Overall, the material and media aspects of interactive multimedia based on Problem-Based Learning are appropriate. Design revisions are made based on the assessment and suggestions from material and media experts until the product is suitable for testing.

Product Trial

Researchers conducted product trials in the fifth grade of SDN Pesantren with six learners: 2 were very proficient, two learners were proficient, and two needed guidance. Researchers used pre-test and post-test questions to measure the improvement of students' learning outcomes.

Table 1. Pre-test and Post-test Results of Product Trial

Action	Average	Improvement
Pre-test	48	35.50
Post-test	83.50	

Table 1 shows that the average pre-test of the product trial was 48, and the average post-test of the product trial was 83.50, so there was an increase of 35.50. So, there is an increase in student learning outcomes after using interactive multimedia based on Problem-Based Learning.

Table 2. Results of Teacher and Learner Responses to Product Trial

Response	Percentage	Criteria
Teacher	100%	Very Feasible
Learners	97%	Very Feasible

Table 2 shows that the teacher's response is 100% with very feasible criteria, and from 6 students, it gets an average of 97% with very feasible criteria. The teacher response questionnaire analysis results show that interactive multimedia based on problem-based learning is based on the characteristics of students, engaging, easy to use, and able to improve students' understanding of the properties of light. The participant response questionnaire analysis results show that interactive multimedia based on Problem-Based Learning is engaging, easy to use, and increases

understanding of the properties of light. Thus, interactive multimedia based on Problem-based Learning is feasible for learning activities.

Product Revision

The results of the product trial showed that there were no revisions from teachers or students. Teachers and students responded positively, and researchers received a feasibility score based on very feasible criteria**.**

Trial Usage

Researchers conducted a usage trial on 20 fifth-grade students of SDN Pesantren using written tests (pre-test and post-test). Testing is carried out to determine whether learning science material on the properties of light using interactive multimedia based on Problem Based Learning that researchers have developed is effective.

Table 3. Pre-test and Post-test Results of the User Trial

Action	Average	Improvement
Pre-test	50.75	33.65
Post-test	84.40	

Table 3 shows that the average pre-test of the usage trial was 50.75 and the average post-test of the usage trial was 84.40, so there was an increase of 33.65. So, there is an increase in student learning outcomes after using interactive multimedia based on Problem-Based Learning.

Table 4. Results of Teacher and Learner Responses for the Usage Trial

Response	Percentage	Criteria
Teacher	100%	Very Feasible
Learners	96.80%	Very Feasible

Table 4 shows that the response from teachers in the usage trial was 100% with very feasible criteria, and 20 students got an average of 96.80% very feasible criteria. Thus, interactive multimedia based on *Problem-Based Learning* received a very feasible response from teachers and students in the usage trial, so interactive multimedia *Problem-Based Learning* is very feasible to use in learning.

Feasibility of Interactive Multimedia Based on Problem-Based Learning

Table 5. Expert Validation Results

Expert	Percentage	Criteria
Material Expert	93.75%	Very Feasible
Media Expert	92.18%	Very Feasible

Based on Table 5. shows that the results of the material expert validation scored 93.75% with very feasible criteria, and the results of the media expert validation scored 92.18% by obtaining very feasible criteria. Based on the results of the material expert validation questionnaire, which contains 20 statements, interactive multimedia based on Problem-Based Learning gets a 75 out of a maximum score of 80, so it gets a percentage of 93.75%. It gets very feasible criteria—based on the results of the media validation questionnaire containing 16 statements, interactive multimedia based on Problem-Based Learning obtained a score of 59 out of a maximum score of 64, thus getting a percentage of 92.18% and obtaining very feasible criteria.

So, interactive multimedia based on Problem-Based Learning is very feasible to use on the material of the properties of light in the fifth grade of SDN Pesantren Semarang City. In addition, the feasibility of interactive multimedia is also supported by the responses of teachers and students. The response results from the fifth-grade teacher amounted to 100%, with very feasible criteria. In addition, researchers also received a response from fifth-grade students in the usage trial of 96.80% with very feasible criteria, so Problem-based interactive multimedia is very feasible to use in learning.

This is supported by previous research that discusses interactive multimedia in natural science subjects, concluding that interactive multimedia is very feasible and well applied in elementary schools [6]. In line with previous research, research that discusses the feasibility of interactive learning multimedia concludes that interactive multimedia is declared feasible for use in learning based on the results of validation of material experts, media experts, teacher responses, and student responses [27].

Effectiveness of Interactive Multimedia Based on Problem-Based Learning

The effectiveness of interactive multimedia based on Problem-Based Learning was tested through a normality test, t-test, and N-gain test using SPSS 27.

Table 6. Normality Test Results

Action	Sig	Criteria
Pre-test	0.159	Normal
Post-test	0.623	Normal

Based on Table 6. which refers to the Shapiro-Wilk normality test, the results of the test on the trial show a pre-test significance value of 0.159 > 0.05, so the data distribution meets the assumption of normality. The post-test normality test results showed a significance value of 0.623 > 0.05, so the data distribution met the normality assumption. After the pre-test and post-test results on the usage trial were declared, the data distribution met the assumptions of normality, and the researchers conducted a t-test (Paired sample t-test).

Table 7. Paired Sample T-Test Results

Action	Mean	Improvement	Sig. (2-tailed)
Pre-test	50.75	33.65	<0.001
Post-test	84.40		

Table 7 shows that the average value of the pre-test of the usage trial was 50.75 and the average value of the post-test of the usage trial was 84.40, so there was an increase of 33.65. Based on the results of the paired sample t-test, the significance value (2-tailed) is <0.001 and based on the criteria, the value is below 0.05, so H_0 is rejected. The significance value (2-tailed) is <0.001 < 0.05, then H_0 is rejected and Ha is accepted. So, there is an increase in student learning outcomes after using interactive multimedia based on Problem-Based Learning.

Table 8. N-Gain Test Results

Action	Mean	Improvement	N-Gain	Criteria
Pre-test	50.75	33.65	0.6913	Medium
Post-test	84.40			

Based on the results of the N-Gain test in the usage trial (large group), we obtained a Mean of 0.6913. The N-Gain test in the usage trial showed a result of 0.6913, including the medium criteria. This indicates that the results of the large group pre-test and post-test increase received moderate criteria. The moderate N-Gain test results suggest that interactive multimedia based on Problem-Based Learning effectively improves the learning outcomes of the properties of light. This shows that the use of interactive multimedia can improve student learning outcomes. Students' learning outcomes have increased after using interactive multimedia [28]. Students' learning outcomes can improve by applying the Problem-based Learning model, which has a good impact on improving students' understanding of the material and learning outcomes. Learning outcomes can be enhanced by using the Problem-Based Learning model [29].

The results of the N-Gain test showed moderate criteria. In contrast, the feasibility test of material and media experts showed very feasible results, and the responses of teachers and students were very feasible. The moderate N-gain results are due to new students using interactive learning media, so students' learning readiness needs to be adequately considered. Students' learning readiness affects students' learning outcomes. Other supporting research explains that learning readiness is one of the factors that can influence and support the success of learning activities. Learning readiness encourages and fosters self-confidence, motivation in the learning process, and learning outcomes. [30]. Optimal learning outcomes are influenced by good learning facilities and good learning readiness [30]. Therefore, the level of students' learning readiness affects students' learning outcomes.

The results of the N-Gain test show moderate criteria due to the different learning styles of each student, which need to be adequately considered because learning styles affect student learning outcomes. Learning style is an internal factor affecting learning outcomes [31]. Other supporting research is research that explains that there is a good impact between learning styles and learning outcomes, so learning styles affect the learning outcomes obtained [31]. So, differences in students' learning styles cause differences in students' learning outcomes.

Conclusion

Developing interactive multimedia based on Problem-Based Learning on the properties of light uses the type of Research and Development (R&D) research with the Borg and Gall model. Interactive multimedia based on Problem-Based Learning on the properties of light is designed using the *Canva* application, which includes a main page, main menu, instructions for use, concept maps, Problem-Based Learning-based learning materials, virtual laboratories (*Dynamic Labs)*, learning videos, interactive quizzes (*Genially*), and developer profiles. The feasibility of interactive multimedia based on Problem-Based Learning from material experts with 93.75% very feasible criteria and media experts with 92.18% very feasible criteria, teacher responses of 100% very feasible criteria and student responses of 96.80% with very feasible criteria. The effectiveness of interactive multimedia based on Problem-Based Learning is shown from the results of the paired sample t-test; namely, there is an increase in the average pre-test and post-test of 33.65 and the significance value (2-tailed) which is <0.001 <0.05, and the N-Gain test results show a value of 0.6913 with moderate criteria. So, interactive multimedia based on problem-based learning was successfully developed, was very feasible, and was effective in improving the learning outcomes of the properties of light for fifth-grade students of SDN Pesantren Semarang City.

Author Contributions

Selviana, the leading researcher, and Aldina Eka Andriani, the research assistant, conducted this research.

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