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Problem-based learning interactive multimedia to optimize elementary school natural and social sciences learning

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ABSTRACT

Teachers have not yet optimally utilized technology-based learning media within the problem-based learning (PBL) model, resulting in low problem-solving abilities among students and poor academic achievement in natural and social sciences. This study aims to describe the development design, assess feasibility, and evaluate the effectiveness of PBL-based interactive multimedia in improving student learning outcomes. This research employed the research and development method using the ADDIE development model. Data collection techniques involved test and non-test methods, while data analysis included normality tests, t-tests, and N-Gain tests. The findings indicate that PBL-based interactive multimedia is highly feasible, with feasibility ratings of 95% from subject matter experts, 93.75% from media experts, 98.75% from teachers, and 95% from students. The effectiveness of this multimedia was supported by t-test results, which yielded Sig. (2-tailed) = 0.000 < 0.05, and an N-Gain score of 0.7350, classified as high. Thus, the developed PBL-based interactive multimedia is feasible and effective in enhancing learning outcomes for phase changes of matter among fourth-grade students at SDN Ngaliyan 05 Kota Semarang. This study implies the development of interactive multimedia, which enhances students' problem-solving skills and facilitates teachers in integrating technology effectively into learning.

Multimedia interaktif berbasis pembelajaran berbasis masalah untuk mengoptimalkan pembelajaran ilmu pengetahuan alam dan sosial di sekolah dasar

Kata Kunci:

perubahan wujud zat, multimedia interaktif, hasil belajar, problem-based learning, integrasi teknologi

ABSTRAK

Guru belum secara optimal memanfaatkan media pembelajaran berbasis teknologi dalam model Problem- Based Learning (PBL), yang mengakibatkan rendahnya kemampuan pemecahan masalah siswa serta prestasi akademik dalam Ilmu Pengetahuan Alam dan Sosial. Penelitian ini bertujuan untuk mendeskripsikan desain pengembangan, menilai kelayakan, dan mengevaluasi efektivitas Multimedia Interaktif berbasis PBL dalam meningkatkan hasil belajar siswa. Penelitian ini menggunakan metode Research and Development dengan model pengembangan ADDIE. Teknik pengumpulan data meliputi metode tes dan non-tes, sedangkan analisis data dilakukan menggunakan uji normalitas, uji-t, dan uji N-Gain. Hasil penelitian menunjukkan bahwa Multimedia Interaktif berbasis PBL memiliki tingkat kelayakan yang tinggi, dengan skor 95% dari ahli materi, 93,75% dari ahli media, 98,75% dari guru, dan 95% dari siswa. Keefektifan multimedia ini *didukung oleh hasil uji-t dengan Sig. (2-tailed) = 0.000 < 0.05, serta skor N-Gain = 0.7350, yang termasuk kategori tinggi. Dengan demikian, Multimedia Interaktif berbasis PBL yang dikembangkan sangat layak dan efektif untuk meningkatkan hasil belajar perubahan wujud zat pada siswa kelas IV di SDN Ngaliyan 05 Kota Semarang. Penelitian ini memiliki implikasi terhadap pengembangan multimedia interaktif yang tidak hanya meningkatkan kemampuan pemecahan masalah siswa, tetapi juga memfasilitasi guru dalam mengintegrasikan teknologi secara efektif dalam pembelajaran.*

Contribution to the literature

This research contributes to:

- Adds new insights into the design and implementation of PBL-based interactive multimedia designed to teach abstract Natural and Social Sciences concepts.
- It deepens the study of integrating technology in learning to increase student engagement. It supports the implementation of the Technological Pedagogical Content Knowledge (TPACK) framework in the context of interdisciplinary learning.
- Provides a new perspective on using PhET Interactive Simulation as a virtual laboratory in learning for technology-based practicum simulation.

1. INTRODUCTION

Natural and social sciences study living things in the universe and their interactions with the environment. They also examine human life as an individual and a social being who interacts with his environment. Through natural and social sciences subjects, students are expected to understand and manage the natural and social environment well. Natural and social sciences emphasize the process of investigation and problem-solving [1].

Learning natural and social sciences at the elementary school level introduces various concepts related to the surrounding environment, such as plants, animals, humans, and the natural world around students [2]. The scope of material for natural and social sciences of the fourth-grade elementary school students includes (1) living things and life processes, which include humans, animals, plants, and their interactions with the environment and health; (2) objects, materials, properties, and their uses which include solid, liquid, and gas objects; (3) energy and its changes which include force, sound, heat, magnetism, electricity, light, and simple planes; and (4) the earth and the universe which includes land, earth, solar system and other celestial bodies. In everyday life, we often see an object change its form to melt, freeze, evaporate, and so on. These events are clearly explained in the changes in the states of matter.

Based on the 2022 Programme for International Student Assessment (PISA) survey conducted by the Organization for Economic Co-operation and Development (OECD), which measures literacy levels in reading, mathematics, and science, the science literacy skills of Indonesian students are still relatively low despite an increase in the rankings [3]. Regarding science ability, Indonesia experienced a decrease in score by 13 points, from 396 in PISA 2018 to 383 in PISA 2022. According to PISA 2022 data, Indonesia ranked 66^{th} out of 81 countries with a score of 383 in science. The data shows students' understanding of science in Indonesia was relatively low. Therefore, efforts are needed to improve the quality of education, especially in science. Since the third grade, science learning has been taught at the elementary school level.

Based on pre-research data collected through observations, interviews, questionnaires, and document analysis of the learning outcomes of fourth-grade students at SDN Ngaliyan 05 Semarang City, several issues have been identified in the teaching of Natural and Social Sciences. These include teachers' suboptimal use of technology-based learning media, which hinders students' understanding. Additionally, using learning media tends to be less interactive, leading to passive student engagement and limiting their problem-solving abilities. This aligns with previous research, highlighting that the lack of technology-based learning media can result in ineffective and unengaging learning experiences [4]. The rapid development of technology supports the creation of practical, simple, and contemporary learning media [5].

The learning model applied by the teacher was suboptimal in creating an effective learning atmosphere. Teachers use conventional learning models and the Project-based Learning (PjBL) model on the changes in the states of matter topic. However, the implementation was not fully optimized. The teacher took full control of learning activities, so the PjBL, ideally a student-centered approach, became teacher-centered because the teacher did not facilitate student interaction. The learning model did not create effective learning, as seen from the low learning outcomes. Previous research supports this finding by showing that learning models significantly influence students' concentration and learning outcomes [6]. Students' learning outcomes can improve if the learning process provides a variety of stimuli, both in visual and audio-visual forms.

The learning outcomes of fourth-grade students of SD Negeri Ngaliyan 05 on the changes in the states of matter were low, evidenced through the analysis of cognitive diagnostic assessments, showing that 78% of 21 students scored below the minimum score, while 22% of 6 students (22%) scored above the minimum score. This outcome showed that the learning was not optimal, and students did not understand the learning material well. The percentage of students who did not understand the material was quite high, indicating certain challenges in the learning process. Previous research revealed that a meaningful and enjoyable learning process should provide a good understanding so students can meet the minimum score [7].

Students often develop misconceptions when learning natural and social sciences, particularly regarding changes in the states of matter, such as melting and condensation, and distinguishing the composition of solid, liquid, and gas particles. These challenges arise because the arrangement of particles in a substance is microscopic and cannot be observed directly. As a result, students struggle to grasp microscopic concepts since they have difficulty connecting abstract ideas with concrete experiences. [8].

Based on the problems described above, it is necessary to make an effort to improve the quality of learning. One way is to utilize innovative learning media, namely interactive multimedia [9]. Interactive multimedia is a tool that combines various elements (text, graphics, images, photos, audio, video, and animation) to convey messages so that it can create more active learning and understand the information conveyed properly [10]. The benefits of using interactive multimedia in learning are improving the quality of the learning process, strengthening memory, and supporting students with various learning styles [11]. Researchers developed interactive multimedia using the Canva application because it can present a variety of stimuli. In addition, virtual laboratories from the PhET Interactive Simulation application and the cK-12 website were used to prepare for practicum activities and facilitate students' problem-solving abilities.

PBL is a learning model that facilitates problem-solving skills [12]. It uses real-world problems as a context for students to learn problem-solving skills and gain critical knowledge about a topic [13]. Therefore, researchers chose to develop PBL-based interactive multimedia because PBL is student-centered, where students play a more active role in the teaching and learning process.

Previously, research has been conducted related to the development of interactive multimedia, including the development of PBL-based interactive multimedia using Canva [4], interactive multimedia development using Appy Pie [14], interactive multimedia development using Articulate Storyline [15], interactive media development using Adobe Animate [16], development of PPT interactive media [17], and the development of interactive Wordwall multimedia using PBL [18]. However, no research has integrated virtual laboratories through PhET Interactive Simulation and the cK-12 website. The virtual laboratories aim to prepare students before doing hands-on practicum.

Other relevant research only focuses on developing PBL-based interactive multimedia with attractive visual, audio-visual, and kinesthetic displays. Research on developing PBL-based interactive multimedia with virtual laboratories from PhET Interactive Simulation and cK-12 sites was limited. Through PhET Interactive Simulation, students can perform virtual simulations or experiments, thus obtaining a symbolic picture of the formation of a science [19]. Therefore, this study aimed to describe the development design of PBL-based interactive multimedia, which has visual, audio-visual, and kinesthetic appeal and is equipped with a virtual laboratory using PhET Interactive Simulation and cK-12 site. PBL-based interactive multimedia is also equipped with interactive edugames from Wordwall to measure students' understanding, thus supporting improved learning outcomes. In addition, this study also aimed to test the feasibility and effectiveness of PBL-based interactive multimedia on the changes in the states of matter. The PBL-based interactive multimedia is expected to improve the learning outcomes of natural and social sciences of the fourth-grade students at SDN Ngaliyan 05.

2. METHOD

2.1 Research Procedure

The type of research used was Research and Development (R&D). Researchers employed the ADDIE development model, which stands for Analysis, Design, Development, Implementation, and Evaluation. After receiving athics approval, the research was conducted. The five stages are described in the Figure 1.

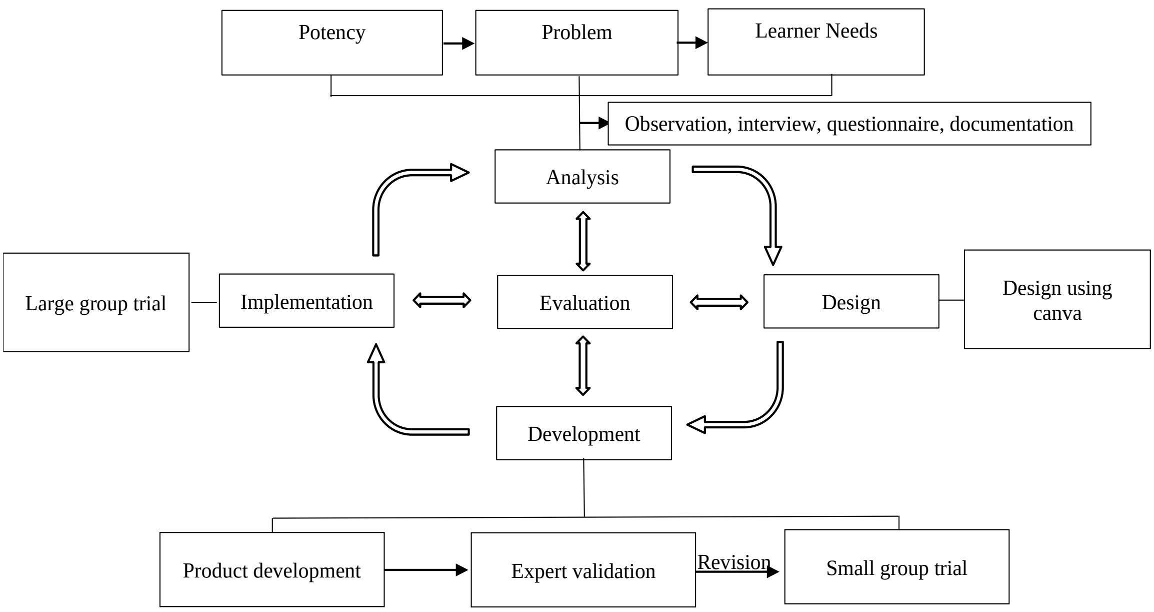


Figure 1. Steps of the ADDIE Model

The research was conducted at SDN Ngaliyan 05, Semarang City, during the odd 2024/2025 academic year semester. It commenced after obtaining consent from both parents and students. The study involved 26 fourth-grade students, six participating in small and 20 in large-group trials. The subjects were selected using purposive sampling, a technique in which researchers deliberately choose participants based on specific criteria. This method ensures that the selected sample meets the research objectives and the necessary criteria. Consistent with previous studies, purposive sampling focuses on individuals with particular characteristics who can provide more relevant and insightful contributions to the research [20].

2.2 Data Collection Techniques

This research employed non-tests (observation, interview, questionnaire, and documentation) and test data collection techniques (pretest and post-test). Observation activities used observation sheets, while interviews were conducted using interview guidelines and interview result sheets. Questionnaires included needs assessment sheets and teacher and student response sheets. Documentation data were collected from the learning outcomes of fourth-grade students at SDN Ngaliyan 05. The pretest and post-test, consisting of multiple-choice questions, were developed based on validity, reliability, discriminability, and difficulty level analyses.

2.3 Data Analysis Techniques

The data analysis technique used was analyzing product feasibility by material and media experts [21]. Expert validation aimed to obtain experts' assessments and opinions regarding the developed product's crucial aspects and feasibility. Feasibility analysis was calculated using a Likert scale. In addition, researchers analyzed the responses of teachers and students. Teachers and students filled out a questionnaire containing several statements about using PBL-based interactive multimedia in learning. Data analysis was done using a normality test, t-test, and N-Gain test. The t-test was conducted to determine the effectiveness of PBL-based interactive multimedia on normally distributed data. The n-Gain test measured the increase in the average score between the pretest and post-test. The criteria for N-Gain scores are presented in Table 1.

Table 1. N-Gain Score Criteria [4]

Interval	Category
N-Gain $\geq$ 0.70	High
0.30 $\leq$ N-Gain $\leq$ 0.70	Medium
N-Gain < 0.30	Low

3. RESULTS AND DISCUSSION

3.1 Development of PBL Interactive multimedia

3.1.1 Analysis

Preliminary research at SDN Ngaliyan 05 revealed several challenges in fourth-grade classrooms. Teachers have not yet fully utilized technology-based learning media, and the existing media lacks interactivity. The learning model remains teacher-centered, limiting the creation of an engaging and effective learning environment. As a result, students struggle with understanding changes in the states of matter, particularly in distinguishing particle arrangements and grasping concepts such as melting and condensation. Misconceptions about these topics further contribute to low learning outcomes. These issues highlight the urgent need for innovative and student-centered learning approaches.

Despite these challenges, SDN Ngaliyan 05 has significant potential to enhance learning through technology. Every classroom is equipped with projectors or LCDs, enabling visual and interactive presentations. A stable internet network supports access to digital resources, while loudspeakers facilitate effective communication during lessons and school activities. Additionally, students have access to Chromebooks, which promote digital literacy and technology-based learning. These resources present an opportunity to implement innovative and modern teaching approaches.

Researchers conducted a needs analysis to address these issues by distributing questionnaires to fourth-grade teachers and students. The goal was to determine the type of learning media required to enhance student understanding. The findings indicated a strong preference for PBL-based interactive multimedia. Prior research suggests that interactive multimedia can enhance students' cognitive abilities and help them grasp abstract concepts [22]. Therefore, this study focuses on developing technology-based learning media as PBL-based interactive multimedia for changes in the states of matter.

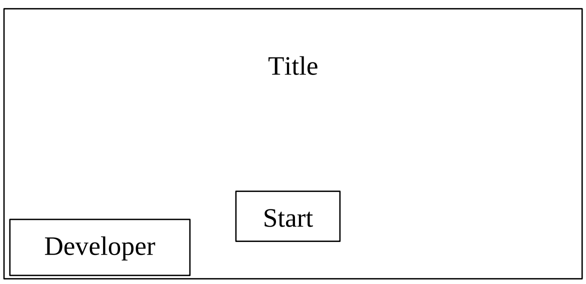
3.1.2 Design

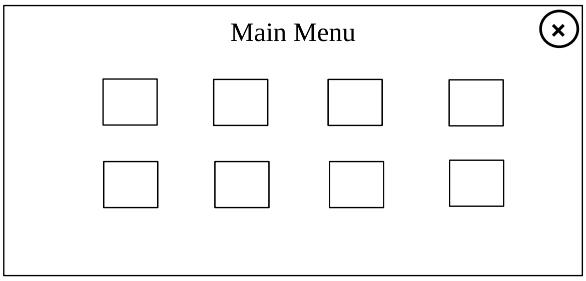
The design stage involved designing products based on the needs questionnaire from the fourth-grade teachers and students at SDN Ngaliyan 05 Semarang City. The product was designed using the Canva application. Canva can produce a media that makes it easier for teachers to explain the material to be taught [23]. The researcher utilized the Canva application by combining text, sound, images, and video into one unit. The combination of these aspects is interactive multimedia. The interactive multimedia developed uses the PBL model. Through this model, learning will be centered on students so that students can work together and exchange knowledge [24].

The prototype of PBL-based interactive multimedia comprises several key components, including a main page featuring material identification and developer information, a main menu, usage instructions, student activity guidelines ("Let's Observe," "Let's Discuss," "Let's Learn," and "Let's Conclude"), learning outcomes, objectives, concept maps, and content on the states of matter. Additionally, it includes a virtual laboratory utilizing PhET Interactive Simulations and cK-12 resources, evaluations, glossaries, references, and developer profiles.

The virtual laboratory with PhET Interactive Simulations and cK-12 resources is a preparatory tool for students before conducting practical experiments. These hands-on activities enhance experiential learning. According to Edgar Dale's Cone of Experience, simulations significantly improve retention, with students remembering up to 90% of what they learn due to their direct engagement in the learning process [25]. The syntax of the PBL model consists of five stages: (1) orienting students to the problem, (2) organizing students for learning, (3) guiding individual and group investigations, (4) developing and presenting their work, and (5) analyzing and evaluating the problem-solving process [13].

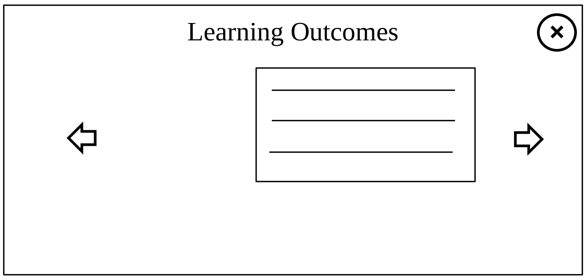
Table 2. Storyboard

Figure	Description
	The image represents the initial page of the PBL-based interactive multimedia, containing material identification, developer identity, and the start button to go to the next menu.

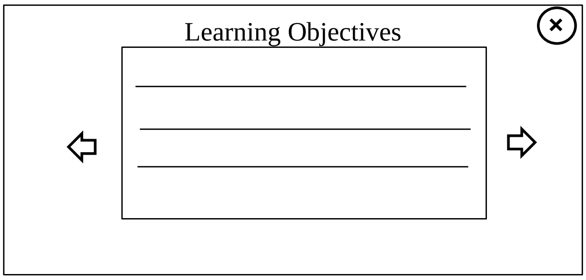


The image represents the main menu page containing various menus:

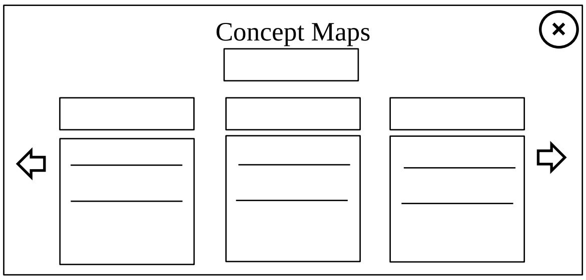
a. Instructions
b. Competencies
c. Materials
d. Summary
e. Evaluation
f. Glossary
g. Bibliography
h. Developer
i. A close button.



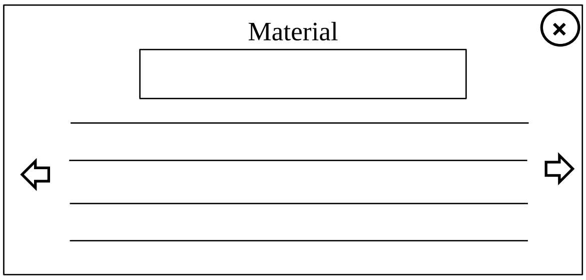
The image represents the competency menu, which contains learning outcomes, a close button, a previous button, and a next button.



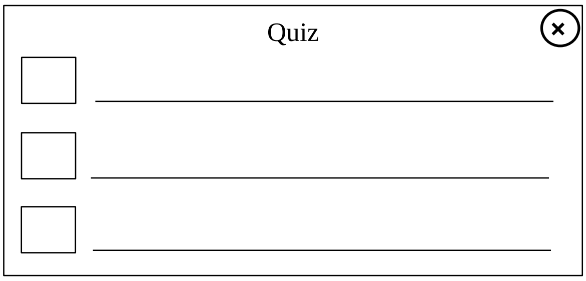
The image represents the competency menu, which contains learning objectives, a close button, a previous button, and a next button.



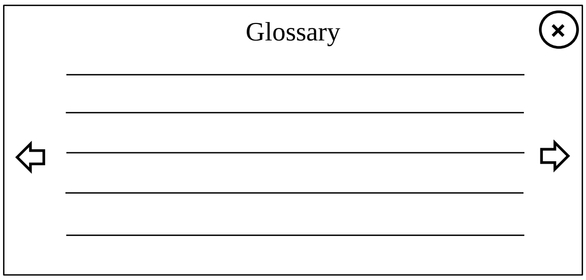
The image represents an example of a concept map containing an explanation of the material.



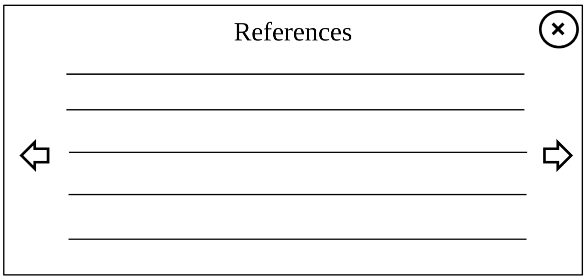
The image represents one example of learning material using PBL syntax. It is accompanied by a close button, a previous button, and a next button.



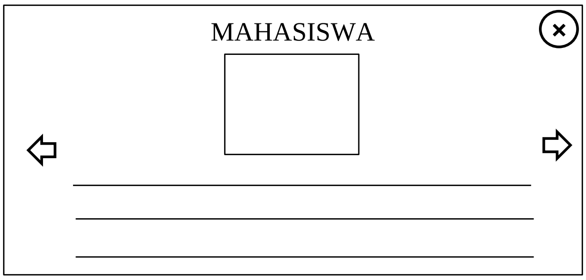
The image represents an example of an interactive edugame design using a Wordwall with a close button.



The image represents an example of a glossary display equipped with a close button, a previous button, and a next button



The image represents an example of a bibliography display equipped with a close button, a previous button, and a next button.



The image represents an example of a developer profile display:

a. Supervisor (Aldina Eka Andriani, S.Pd., M.Pd.)
b. Student (Insania Rizkyning Praja)

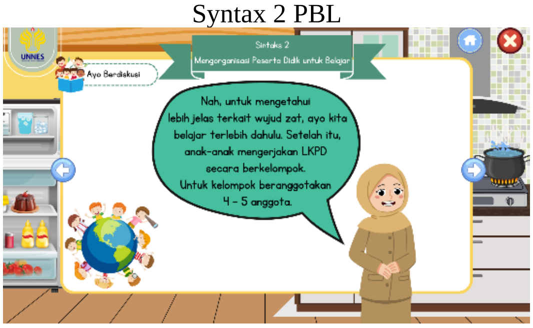
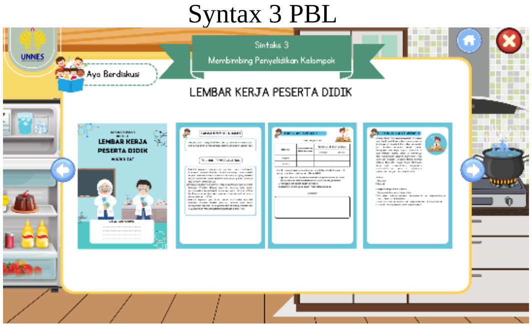
This display comes with identity information, a close button, a previous button, and a next button.

3.1.3 Development

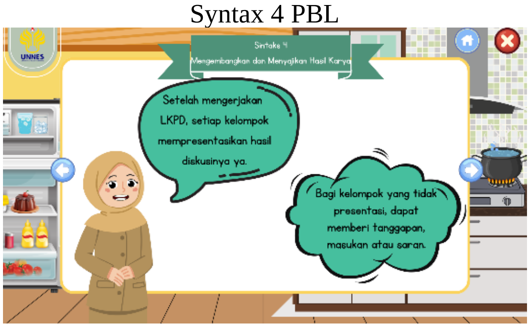
The collected materials—including videos, audio, animations, images, and preparatory content—were developed into an initial prototype of PBL-based interactive multimedia. This prototype was then subjected to validation by media and material experts. The validation results served as a basis for improvement. During this process, material experts provided feedback on placing the "Changes in the States of Matter" topic. Initially, this material was introduced in the second syntax of the learning steps. However, after review, it was recommended to be moved to the third syntax to better align with the logical flow and students' conceptual understanding.

The recommendation was based on the notion that students should first explore phenomena before being introduced to abstract concepts. By restructuring the sequence, the learning experience becomes more student-centered and aligns with constructivist principles. The third syntax, "Guiding Individual and Group Investigations," involves students conducting practicum activities, followed by descriptions of state changes. This shift also allows for more meaningful discussions and deeper engagement with the content. This adjustment ensures that the practicum fosters inquiry-based learning rather than mere verification. Inquiry learning emphasizes scientific thinking and is often integrated with hands-on activities [26]. Through active participation, students are encouraged to formulate hypotheses and analyze results independently. Furthermore, media experts who evaluated the technical and design aspects stated that the developed product met the expected criteria without requiring further revision. Their evaluation covered elements such as interface consistency, usability, and visual appeal. The results of the revised PBL-based interactive multimedia development are presented in Table 3.

Table 3. PBL-based Interactive Multimedia Design

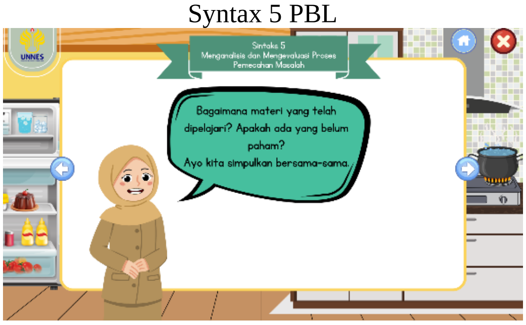
Design	Description
Main Page 	The main page contains the identification of changes in the states of matter and the identity of the developer.
Main Menu 	The main menu contains instructions for use and student activities, competencies, materials, summaries, evaluations, glossaries, bibliographies, and developers.
Syntax 1 PBL 	Syntax 1 (orienting students to the problem) presents questions related to the picture presented.
Syntax 2 PBL 	Syntax 2 (organizing students to learn) prepares students to learn in groups.
Syntax 3 PBL 	Syntax 3 (guiding individual and group investigations) guides students to work on the student worksheet.

Syntax 4 PBL



Syntax 4 (developing and presenting the work results) guides students in groups to present their learning outcomes to the class. Groups that do not present are allowed to provide responses, input, or suggestions.

Syntax 5 PBL



Syntax 5 (analyzing and evaluating the problem-solving process) guides students and the teacher in discussing the material they have learned, identifying areas of confusion, and drawing conclusions together.

PhET Interactive Simulation

A virtual laboratory using PhET Interactive Simulation prepares students for direct practicum. Students can simulate practicum using technology.

A song about the state of matter

Researchers created songs related to the state of matter material to facilitate students' understanding of it.

Material mapping in interactive multimedia is divided into two lessons. The first lesson introduces changes in the states of matter: solid, liquid, and gas. The second lesson covers specific phase changes, including melting, freezing, evaporation, condensation, sublimation, and crystallization. Each lesson is enriched with a concept map, material-related songs featuring audio from researchers, and interactive educational games from Wordwall.

PBL-based interactive multimedia was designed for smartphones or laptops and can be accessed via a provided link. Integrating technology into learning enhances student engagement [27] and allows for independent exploration, fostering greater enthusiasm and comprehension. Additionally, this multimedia approach is practical, as it enables students to learn anytime and anywhere beyond the confines of the classroom.

3.1.4 Implementation

The validated developed product deemed feasible by a team of experts was then implemented in the field. Researchers conducted a large-group product trial with 20 fourth-grade students at SDN Ngaliyan 05, excluding those who had participated in the small-group trial. The trial was conducted systematically under direct researcher supervision to ensure optimal multimedia usage. After the learning session, teachers and students provided feedback on using interactive multimedia for PBL on changes in states of matter.

3.1.5 Evaluation

Evaluation was obtained from the feasibility test results by providing validation questionnaires to material experts and media experts [28] and teacher and student response questionnaires. In addition, an evaluation was conducted to determine students' learning outcomes regarding the material that had been presented. The effectiveness of PBL-based interactive multimedia was shown from the increase in pretest and post-test scores through the normality tests, t-tests, and N-Gain tests.

3.2 The Feasibility of PBL-based Interactive Multimedia

Material and media experts carried out the feasibility assessment of PBL-based interactive multimedia. Other studies state that the feasibility test is carried out by providing validation questionnaires to material and media experts [29]. In addition, the fourth-grade teachers and students of SDN Ngaliyan 05 Semarang City carried out the feasibility assessment of PBL-based interactive multimedia. This assessment was conducted to determine whether the products developed followed the criteria, were feasible, and could be tested in learning.

Table 4. Media and Material Expert Validation Result

Expert Validator	Percentage	Criteria
Material	95%	Very Feasible
Media	93,75%	Very Feasible
Average	94,37%	Very Feasible

Based on Table 4, the validity test results indicate that material experts rated the interactive multimedia with a 95% feasibility score. In comparison, media experts provided a 93.75% feasibility score, both classified as "very feasible." These assessments were conducted using a questionnaire prepared by the researcher, evaluated on a Likert scale ranging from 1 (less feasible) to 4 (very good) [30]. For media experts, the questionnaire contained 16 questions with a total score of 64, covering three key aspects: quality of content and purpose, construction, and technical/display. The technical/display aspect received the highest percentage at 40.7%, as the PBL-based interactive multimedia was found to function effectively, be user-friendly for students and teachers across various devices such as laptops and smartphones, and feature an attractive design. The interactive nature of the multimedia also increased student engagement, allowing them to explore learning materials in multiple ways [31].

The material experts' questionnaire consisted of 20 questions with a total score of 80, assessing five aspects: accuracy with learning objectives, alignment with students' critical thinking levels, support for interactive multimedia content, stimulus for material comprehension, and appropriateness for supporting lesson content such as facts, concepts, principles, and generalizations. The aspect of support for interactive multimedia content received the highest rating at 33%, as the material was delivered using the PBL model. This model encourages students to think critically, develop problem-solving skills, and acquire in-depth knowledge on a topic [13]. Based on the assessment of media and material experts, the PBL-based interactive multimedia is very feasible to test.

Table 5. Results of Teacher and Student Response Questionnaire

Respondents	Percentage	Criteria
Teacher	98,75%	Very Feasible
Students	95%	Very Feasible
Average	96,87%	Very Feasible

Table 5 presents the percentage of teacher and student responses. The teacher's response received a rating of 98.75%, while the student's response was rated at 95%, falling into the "very feasible" category. Based on the validity test results from material experts, media experts, teacher responses, and student responses, it can be concluded that PBL-based interactive multimedia is highly suitable for learning.

3.3 The Effectiveness of PBL-based Interactive Multimedia

The effectiveness of PBL-based interactive multimedia on changes in the states of matter is assessed by analyzing student learning outcomes through pretest and post-test scores. The pretest scores are obtained from questions completed by students before using the PBL-based interactive multimedia. In contrast, the post-test scores are derived from questions answered after the learning process. The results of the pretest and post-test assessments are presented in Table 6.

Table 6. Pretest and Posttest Results

Aspects	Pretest Score	Post-test Score
Average	49,2	83
Highest score	72	96
Lowest score	32	72

Based on Table 6, the average learning outcomes increased by 33.8 points, rising from a pretest average of 49.2 to a post-test average of 83. This data indicates a significant improvement in learning outcomes, aligning with previous studies showing notable increases in pretest and post-test scores through interactive multimedia [14]. The data analysis was conducted using SPSS 30, where researchers performed normality tests, paired sample t-tests, and N-Gain tests on students' pretest and post-test scores [32].

The normality test assessed whether the research data followed a normal distribution. Specifically, the Shapiro-Wilk test was employed using SPSS 30, and the results of the pretest-posttest normality test are presented in Table 7.

Table 7. Normality Test Results on Pretest and Post-test

	Statistics	df	Sig.
Pretest	.961	20	.566
Posttest	.961	20	.573

The normality test criterion states that data is normally distributed if the Sig. value is greater than 0.05. Conversely, if the Sig. value is less than 0.05. The data is not normally distributed [33]. Table 5 presents the normality test results for the pretest and post-test. According to the table, the Sig. value for the pretest data is 0.566 (>0.05), and for the post-test data, it is 0.573 (>0.05). These results suggest that both sets of data do not significantly deviate from a normal distribution. Therefore, the assumption of normality for parametric tests is satisfied. Since both values exceed 0.05, it can be concluded that the data is normally distributed, meeting the requirement for conducting a paired sample t-test.

A t-test can be performed if the normality test confirms that the data is normally distributed. The paired sample t-test was conducted using SPSS 30 to assess the effectiveness of PBL-based interactive multimedia. The results of the t-test are presented in Table 8.

Table 8. Paired Sample T-test Result

Action	Mean	Std. Deviation	Std. Error Mean	Sig. (2-tailed)
Pretest - Postest	33.800	7.619	1.703	0.000

The criterion for the Paired Sample t-test is as follows: If the Sig. (2-tailed) value is greater than 0.05, there is no significant difference between the pretest and post-test results. Conversely, if the Sig. (2-tailed) If the value is less than 0.05, a significant difference exists.

Based on Table 8, the Sig. (2-tailed) value is 0.000, which is less than 0.05. Therefore, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_a) is accepted. This indicates a significant difference between the pretest and post-test data. In other words, the use of PBL-based interactive multimedia is proven effective in improving the learning outcomes of fourth-grade students.

Additionally, the N-Gain test measures the average increase in pretest and post-test scores. In this study, the N-Gain test was conducted using the SPSS 30 application, and the results are presented in Table 9.

Table 9. N-Gain Test Results

Action	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain	20	.50	1.00	.7350	.11243
Valid N (listwise)	20				

Based on Table 9, the N-Gain test results indicate that the learning outcomes of fourth-grade students at SDN Ngaliyan 05 improved when using PBL-based interactive multimedia. The average N-Gain score increased to 0.7350, placing it in the high category. This level of improvement shows a substantial gain in conceptual understanding among students. This suggests that PBL-based interactive multimedia is effective in enhancing student learning, particularly in Natural and Social Science subjects related to changes in the states of matter. Previous studies have demonstrated improved student learning outcomes after implementing PBL-based interactive multimedia [4].

Several factors contribute to the high-category increase in the average N-Gain score. First, readiness before learning plays a crucial role. Physical and mental readiness influences students' ability to engage with and absorb new material [2]. This readiness influences each other and is necessary for individuals to achieve optimal readiness in the learning process [34]. In addition to physical and mental readiness, high-grade students are facilitated to use smartphones according to learning hours so that students are accustomed to using technology as needed. (2) Second, students' learning styles impact the effectiveness of interactive multimedia. PBL-based interactive multimedia accommodates diverse visual, auditory, and kinesthetic learning styles. Visual learners benefit from presenting material in text and image formats, which aligns with research indicating that visual learners absorb information effectively through diagrams, maps, and posters [35]. Auditory learners are supported through audio explanations of the material, which can be played as needed, and instructional videos tailored to student characteristics. Kinesthetic learners engage with virtual laboratories using PhET Interactive Simulations and the CK-12 platform, which helps them prepare for hands-on experiments related to changes in the states of matter, such as melting and condensation.

Third, a comfortable learning environment contributes to improved student outcomes. A safe and conducive learning setting enhances student interaction, encourages active participation, and facilitates comprehension of abstract concepts [36]. This positive environment enables students to grasp complex material more effectively and retain knowledge longer.

Based on these factors, it can be concluded that PBL-based interactive multimedia is an effective tool for improving learning outcomes in Natural and Social Sciences subjects, particularly in topics related to changes in the states of matter among fourth-grade students at SDN Ngaliyan 05, Semarang City. This study aligns with existing research, highlighting that interactive multimedia facilitates comprehension and accommodates diverse learning speeds, benefiting students requiring additional time to grasp concepts [37]. Integrating interactive multimedia into the learning process benefits students and the learning environment [38]. The learning model determines the success of the learning process; one of the learning models that can improve the quality and learning outcomes is PBL [39]. The PBL model invites students to solve problems and provide solutions [40] and encourages students to make decisions from various points of view carefully, thoroughly, and logically [41]. Other research shows that the PBL model has an effect in improving student learning outcomes [42].

PBL-based interactive multimedia offers several advantages. First, incorporating digital technology makes learning more engaging and interactive, making lessons more dynamic, exploratory, and less monotonous compared to traditional classroom methods. Second, it provides flexible access, as students can use the platform anytime and anywhere with an internet connection. This allows for independent study and material revision beyond formal lesson hours. Third, it promotes active learning and knowledge construction, as the PBL approach encourages students to build their understanding, enhance inquiry skills, and apply logical reasoning to problem-solving [39]. Fourth, it enhances understanding of abstract concepts, as visual elements such as animations, images, videos, and simulations help students grasp difficult topics that might otherwise be challenging to understand through text-based or verbal instruction alone. Research supports that hands-on learning, such as simulations, results in a 90% retention rate, as students are actively involved in the learning process [25].

Despite its advantages, PBL-based interactive multimedia has certain limitations, primarily its dependence on a stable internet connection. This can challenge students and educators in areas with limited network access. To address this issue, future research should focus on developing offline-compatible interactive multimedia to ensure accessibility in diverse learning environments. Implementing offline features would enable students to engage with educational content without internet dependency, expanding its usability in remote or underserved areas. Overall, this research highlights the potential of interactive multimedia to enhance students' problem-solving skills while supporting teachers in integrating technology into the learning process.

4. CONCLUSION

Based on the results and discussion, the feasibility of PBL-based interactive multimedia was rated very feasible, with 95% from material experts, 93.75% from media experts, 98.75% from teachers, and 95% from students. Additionally, the N-Gain test confirmed its effectiveness in the high category. The t-test results also indicated a significant difference between pretest and post-test scores. PBL-based interactive multimedia supports diverse learning styles and enhances students' problem-solving abilities through various stimuli. This study concludes that the development of PBL-based interactive multimedia was successful, highly feasible, and effective in improving learning outcomes in Natural and Social Sciences, specifically regarding changes in the states of matter, for fourth-grade students at SDN Ngaliyan 05, Semarang City. The findings of this research highlight the importance of interactive multimedia in fostering students' problem-solving skills and assisting teachers in integrating technology into learning.

AUTHOR CONTRIBUTION STATEMENT

IRP contributed to conducting research, processing data, and drafting the article, and AEA provided guidance and direction during the research process.

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