Jurnal Pijar MIPA
https://jurnalfkip.unram.ac.id/index.php/JPM

ISSN 1907-1744 (Print)
ISSN 2460-1500 (Online)

Development of Multimedia-based on Problem-Based Learning to Improve Learning Outcomes in Energy Transformation

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Received: May 26, 2026. Accepted: July 3, 2026. Published: August 31, 2026

Abstract: Teachers have not optimally used technology-based learning media, such as interactive edugames, resulting in poor student learning outcomes on the topic of energy transformation. This study aims to describe the development and design, and to test the feasibility and effectiveness of multimedia-based problem-based learning (PBL) to improve fourth-grade students' learning outcomes on the topic of energy transformation at SDN Tambakaji 03, Semarang City. This research used the Research and Development (R&D) method with the ADDIE model. The subjects were 28 fourth-grade students at SDN Tambakaji 03, Semarang City. Data collection techniques included non-test methods (observations, interviews, questionnaires, and documentation) and test methods (pretests and posttests). Data analysis techniques used included a normality test, a paired-samples t-test, and an N-Gain test. The results showed that the Multimedia, based on Problem-Based Learning for the topic of energy transformation, was designed in Canva and further developed in Genially. The feasibility results showed a content expert score of 95% and a media expert score of 96%, both categorized as "highly feasible," supported by teacher response questionnaire results of 97.5% and student response questionnaire results of 97%, both also categorized as "highly feasible." The effectiveness of the multimedia was indicated by an increase in pretest and posttest scores from 72.7 to 83.6, supported by a paired-samples t-test ($p = 0.000 < 0.05$) and an N-Gain score of 0.4439 (moderate criterion). The study concludes that multimedia-based problem-based learning was successfully developed, highly feasible, and effective in improving fourth-grade students' learning outcomes on energy transformation at SDN Tambakaji 03, Semarang City. This study is still limited to the essential concepts of energy transformation.

Keywords: Energy Transformation; Learning Outcomes; Multimedia; Problem-Based Learning.

Introduction

Natural science is the study of natural phenomena, such as living organisms, inanimate objects, and their interactions in the universe. Natural science is knowledge obtained through a series of scientific processes, such as observation, experimentation, analysis, drawing conclusions, and the systematic formulation of theories [1]. The nature of natural science has four dimensions: as a product, as a process, as an attitude, and as technology [2]. The scope of natural science refers to the boundaries or coverage of the material to be studied. The scope of natural science in the fourth grade of elementary school includes the characteristics of living organisms, the states of matter and their changes, energy and its changes, electricity, magnetism, and forces [3].

Science education not only emphasizes understanding the natural world but also aims to equip students with the ability to think critically, logically, and systematically when examining the relationship between humans and their environment. This aligns with the learning outcomes for science in the Merdeka Curriculum, which emphasizes two main elements conceptual understanding and process skills [4]. Through the conceptual understanding element, students are expected to be able to understand various natural phenomena scientifically, while through the process skills element, students are trained to observe, classify, draw conclusions, communicate, and solve problems based on the scientific process [5]. Therefore, the implementation of science education must be adapted to students' characteristics and developmental stages to achieve learning objectives optimally.

Elementary school students are in the concrete operational stage of cognitive development, typically between ages 7 and 11. At this level, students prefer to play, move around, work in groups, and engage in hands-on activities. Learning in elementary school must be adapted to these cognitive developmental characteristics to optimize the learning process. Therefore, teachers need to provide authentic learning experiences through the use of relevant media and learning environments [6]. Learning designed to be engaging and relevant will provide meaningful learning experiences, thereby enhancing student motivation and learning outcomes.

Instructional media refers to anything that can be used to convey messages and stimulate students thoughts, feelings, attention, and interest in the learning process [7], thereby enhancing students understanding of the material being studied. Ideal learning media are those systematically designed to help students understand lesson material in a more tangible, engaging, and easily comprehensible way by combining visual, auditory, and interactive elements [8]. Effective learning media can help students transform abstract concepts into concrete ones. One way to do this is by using

How to Cite:
Y. A. Ghumaisha and A. E. Andriani, "Development of multimedia based on problem-based learning to improve learning outcomes in energy transformation," *J. Pijar MIPA*, vol. 21, no. 4, pp. 812–820, Aug, 2026. https://doi.org/10.29303/jpm.v21i4.12226

multimedia, which helps students form mental images of these abstract concepts.

Multimedia is a form of educational technology that combines text, images, audio, video, and animation with interactive features that students can access and control directly. The main components of multimedia are text to convey information, images and illustrations to clarify visual meaning, audio to support the narrative, and video and animation to visualize abstract concepts in a dynamic form so that they are easily understood by students [9]. Using multimedia in the learning process can make learning more enjoyable and less monotonous, thereby increasing student engagement.

Problem-Based Learning is an educational approach designed to equip students with the knowledge and skills they need to solve problems, think critically, be creative, learn independently, and work collaboratively in teams [10]. In the Problem-Based Learning model, students are presented with real-world situations that require problem-solving, making the learning process more meaningful and applicable to daily life.

Based on preliminary research conducted through observation, interviews, and needs assessments, it was found that the technology-based learning media used by teachers were not yet optimal. Teachers were already using Canva-based PowerPoint presentations, but these contained only the subject matter and lacked concrete visual aids. Instead, instruction relied on lecture-based, teacher-centred methods, causing students to struggle with understanding the concepts being taught. Teachers have not yet incorporated interactive edugames into the learning media they use, whereas elementary school students are more interested in interactive learning media accompanied by engaging animations and concise text descriptions [11].

Teachers have not yet fully optimised the use of the Problem-Based Learning model, as some components remain ineffective. The component that has not been implemented in the learning process is the second component, namely organizing students for learning. Teachers merely direct students to work through the exercises on their worksheets after presenting the learning material. Failure to implement the second step in the Problem-Based Learning model has several consequences: learning becomes less structured, collaboration is suboptimal, student engagement declines, and consequently, student learning outcomes do not improve, resulting in suboptimal learning outcomes [12].

This is supported by the low learning outcomes of fourth-grade students at SDN Tambakaji 03 on the topic of energy transformation. Based on the results of the cognitive diagnostic assessment on the topic of energy transformation, 60% of the 16 students scored below the minimum competency standard (MCS), while 40% of the 12 students scored above the minimum competency standard (MCS). Thus, it can be concluded that learning about energy transformation has not yet been optimal. Optimal learning outcomes can be achieved if the learning process is active, creative, and innovative, and supported by appropriate media and methods [13]. Based on the analysis results, there are still misunderstandings regarding the definition and concepts of energy conversion; therefore, innovative learning media are needed to visualize the concepts more clearly so that they are easier for students to understand.

The development of interactive learning media has provided an innovative solution to various challenges in the learning process. By combining text, images, animations, videos, and audio in a single, unified interface, interactive media can present material in a more concrete and easily understandable way. Multimedia makes learning more engaging for students because it incorporates animations, videos, audio, images, and interactive quizzes [14]. Furthermore, interactive features such as navigation buttons and quizzes can encourage students' active engagement in the learning process.

Genially is a web-based digital platform developed to facilitate interactive learning through the presentation of attractive, dynamic, and easily accessible content [15]. Genially's user-friendly interface and diverse features can make content delivery more engaging and help students actively participate in the learning process, making the material easier and more enjoyable to understand. Genially also offers various learning support features, such as interactivity, animations, hyperlinks, and navigation, that enable students to engage directly with the material. Genially's strength in learning lies in its ability to present material in a more engaging and interactive way [16]. Additionally, Genially helps teachers design learning materials tailored to students' needs and characteristics.

A previous study titled “Development of Genially-Based Interactive Multimedia on the Subtheme of Energy Conservation” received a student response rate of 92.2%, which falls into the “highly feasible” category [17]. Another study concluded that the use of multimedia-based problem-based learning (PBL) using Genially is valid, highly feasible, and effective in improving students' cognitive learning outcomes in science education [18].

Although some previous studies have developed multimedia-based Problem-Based Learning using Genially in elementary schools, most of these studies have focused solely on multimedia development without integrating the full framework of Problem-Based Learning into learning activities [19]. To date, there has been limited research integrating Problem-Based Learning, Genially multimedia, and interactive edugames into a single educational product. Therefore, there is a need to develop multimedia that can combine these three components to support more meaningful learning tailored to students’ characteristics.

The novelty of this study lies in the development of a multimedia-based problem-based learning (PBL) program, built on the Genially platform, that integrates all components of PBL with an interactive educational game, Snakes and Ladders, on the topic of energy conversion. The product developed in this study combines problem orientation, investigation, information gathering, presentation of results, and evaluation into a single multimedia package [20]. In addition, the material is designed to help students understand the four forms of energy transformation they commonly encounter in daily life, such as electrical energy, light, motion, and sound.

Based on the results of the needs analysis, the researcher developed a multimedia-based problem-based learning in Energy Transformation using Genially to improve the learning outcomes of fourth-grade students at SDN Tambakaji 03, Semarang City. The objectives of this study were to (1) describe the design development of the Multimedia-based on Problem-Based Learning; (2) test the

feasibility of the Multimedia-based on Problem-Based Learning; and (3) test the effectiveness of the Multimedia-based on Problem-Based Learning.

Research Methods

This type of research is Research and Development (R&D), which is used to produce a product through a process of identifying potential problems, design, development, and evaluation in order to establish an empirical foundation for creating an effective product or model for learning [21] using the ADDIE development model, which consists of five stages (1) analysis; (2) design; (3) development; (4) implementation; and (5) evaluation [22]. Each stage in the ADDIE development model is interrelated and has specific objectives: (1) The Analysis stage aims to identify potential learning issues and collect initial data to inform the design of a product that aligns with the needs of teachers and students; (2) Design is the stage involves designing and developing the product based on the results of previous analysis of the needs of teachers and students, resulting in Multimedia-based on Problem-Based Learning on the topic of energy transformation; (3) Development is the stage of refining the product through a validation process conducted by subject matter experts and media experts to determine its suitability before testing with students; (4) Implementation is the stage of applying the developed product to learning activities. At this stage, product testing is conducted in phases a small scale pilot test involving 6 students and a large scale pilot test involving 22 students; (5) Evaluation is the final stage in the ADDIE development model, it involves analysing the data obtained from the trials to determine the effectiveness of the product developed by the researcher by analysing student learning outcomes before and after using Multimedia-based on Problem-Based Learning.

The subjects of this study were 28 fourth-grade students at SDN Tambakaji 03 in Semarang City, comprising 17 girls and 11 boys. Data collection employed two methods: non-test methods (observation, interviews, questionnaires, and documentation) and test methods (pretest and posttest) [23]. The data were then analyzed using a normality test, a paired-sample t-test, and an N-Gain test to determine the effectiveness of multimedia-based problem-based learning.

Results and Discussion

This study focuses on the design, development, feasibility, and effectiveness of a multimedia-based problem-based learning in energy transformation to improve the learning outcomes of fourth-grade students at SDN Tambakaji 03, Semarang City.

Development of Multimedia-based on Problem-Based Learning

This study employs the ADDIE development model, consisting of five stages analysis, design, development, implementation, and evaluation. This section presents the research results in accordance with the stages carried out, along with the findings from each stage.

Analysis

This stage aims to identify learning needs, analyze existing problems, and determine student characteristics through cognitive diagnostic assessments. The primary focus of this stage is to identify the needs and problems encountered in the learning process to determine the gap between the ideal conditions and the actual conditions in the field [24]. The analysis stage aims to identify potential learning problems and collect initial data to inform product design, ensuring the product aligns with the needs of teachers and students.

Preliminary research found that teachers were not making optimal use of technology-based learning media, specifically interactive edugames. Consequently, the learning media used were not interactive, wich lead to a decline in student motivation [25]. This is evidenced by the fact that 60% of students still failed to meet the criteria for achieving learning objectives, resulting in low learning outcomes.

SDN Tambakaji 03 has excellent potential for implementing technology-based learning. The school has fairly comprehensive facilities and infrastructure to support teaching and learning, including LCD projectors, speakers, and an internet network for digital learning. Based on the results of the preliminary study and the needs of teachers and students, the researcher developed Multimedia-based on Problem-Based Learning to improve the learning outcomes of fourth-grade students at SDN Tambakaji 03 in Semarang City on the topic of energy transformation.

Design

This design phase involves planning and developing a product based on the prior analysis of teachers' and students' needs, resulting in a usable multimedia product grounded in Problem-Based Learning (PBL) that covers energy transformation. In this stage, specific, measurable, achievable, and realistic learning objectives are formulated. All these elements are incorporated into a systematic and structured instructional design. During the design phase, the instructional media will be designed using software, and visual designs will be created [26].

At this stage, the researcher began developing a multimedia learning resource based on Problem-Based Learning, designed using Canva, a free graphic design application used to create visual components for learning resources [27] and then further developed through Genially, a web-based digital platform designed to facilitate interactive learning through the presentation of attractive, dynamic, and easily accessible content [15] to improve fourth-grade students' learning outcomes on energy transformation.

The advantages of Genially in education include presenting material in a more engaging and interactive way, thereby preventing monotony; providing interactive features that boost students' active participation; and supporting technology-based learning relevant to the needs of the digital generation [16]. Genially also supports the use of visual, audio, and audiovisual features that can increase student motivation during the learning process. The following presents the results of a product development project in the form of a Multimedia design based on problem-based

learning, used in science education to teach energy transformation.

Figure 1. Cover of a Multimedia Course Based on Problem-Based Learning

The opening section of the Multimedia-based on problem-based learning begins with the title "Multimedia-based on Problem-Based Learning in Energy Transformation Electricity, Light, Motion, and Sound," a start button, images related to energy transformation, grade levels, phases, and the multimedia developers. The cover page also features illustrations of tools that utilize energy transformations in daily life as an introduction to the material to be studied [28].

The use of semi-concrete elements and a balanced color scheme helps students understand the abstract concept of energy transformation in a more tangible and accessible way. Furthermore, the use of engaging elements relevant to the lesson content can help convey information more clearly, thereby enhancing students' motivation to learn [29].

Figure 2. Main menu Multimedia-based on Problem-Based Learning

The main menu of the Multimedia-based on Problem-Based Learning contains several submenus in the form of interactive buttons that open new pages when clicked, making it easier for students to understand the learning steps they will follow [30]. The main menu of the Multimedia-based on Problem-Based Learning system contains 1) User Guide Menu, to help students understand the functions of each button in the Multimedia-based on Problem-Based Learning system; 2) Activity Guide Menu, to help students understand the activities to be performed during the learning process; 3) Learning Modules 1 and 2, to help students access the learning stages and materials; 4) Evaluation menu, containing evaluation quizzes that can be completed after Learning Modules 1 and 2 are completed; 5) Glossary, to help students understand new vocabulary encountered during the learning process; 6) Bibliography, to identify the sources of citations used in the Multimedia-based on Problem-Based Learning; 7) Developer Profile, to identify the developer profile for the Multimedia-based on Problem-Based Learning.

Figure 3. Syntax 1 Problem-Based Learning

In the development of Multimedia based on problem-based learning, the researcher provides learning stimuli in the early stages of the activity through simple activities related to energy transformation. The purpose of these stimuli is to capture students' attention [31]build an initial understanding of the material and help students understand problems in context so they can actively engage in the learning process and develop critical thinking skills to identify and solve problems.

Figure 4. Syntax 2 Problem-Based Learning

At this stage, students are divided into several groups based on the results of a cognitive diagnostic assessment, with categories of highly proficient, proficient, and in need of guidance. Students are given worksheets to support discussion and problem-solving activities. Grouping students based on their level of understanding can foster more effective collaboration among students and encourage mutual assistance in solving learning problems [32].

Figure 5. Syntax 3 Problem-Based Learning

Figure 6. Snakes and Ladders Game in Multimedia-based on Problem-Based Learning

In this third session, students accessed Multimedia materials based on problem-based learning in groups to build an understanding of the given problem. Afterwards, students completed the tasks on the student worksheet (LKM) by utilizing the available learning resources. In the multimedia-based problem-based learning, the researcher developed a Snakes and Ladders game as part of the learning activities. Squares 1 and 2 in the Snakes and Ladders game are questions that students must answer in groups on the distributed worksheets. After the questions on the worksheets are completed, students take turns rolling the dice to determine the pawn's move. Each square contains a question with varying points based on the difficulty level, a bonus move forward, or a bomb that moves the pawn backwards. In addition to using interactive edugames, students also utilize concrete materials to aid in problem-solving related to the topic of energy transformation [33].

Figure 7. Use of Multimedia-based on problem-based learning, concrete materials, and group discussions

The use of interactive educational games and concrete materials is intended to increase students' motivation to understand the concept of energy transformation in a more tangible way, thereby making the material easier to understand [34].

Figure 8. Syntax 4 Problem-Based Learning

In the fourth phase, developing and presenting work, students who have completed their worksheets come to the front of the class to present the results of their group discussions. Other groups provide feedback, additional information, or suggestions regarding the presentations. This phase encourages students' active engagement in the learning process [35] and helps develop their critical thinking, communication, and collaboration skills.

Figure 9. Syntax 5 Problem-Based Learning

In step 5, which involves analyzing and evaluating the problem-solving process, students and teachers reflect on the outcomes of the discussions and learning activities conducted. In the multimedia-based problem-based learning, the researcher presents instructional videos tailored to the topic of energy transformation. The videos combine moving images, text, and sound to capture students' attention [36], helping them grasp learning concepts more clearly and thereby supporting the achievement of learning objectives.

Development

This stage aims to produce a product that has been designed and created by the researcher, developed, and then validated to test its validity [37]. The validation process, conducted by subject-matter and media experts, aims to determine the product's suitability before it is tested with students. Content validation is conducted to assess the alignment of the materials' content with learning outcomes and learning objectives, as well as the conceptual appropriateness of the fourth-grade energy transformation material. Meanwhile, media validation is conducted to assess the suitability of design aspects, including visuals, audio, video, and animations, as well as the ease of use of the Multimedia-based on Problem-Based Learning.

Implementation

This implementation phase involves applying the developed product to learning activities. The implementation phase is conducted to assess the effectiveness of the developed learning media in the learning process [26]. Product testing is carried out in two stages: small-scale and large-scale testing. Small-scale testing is conducted to observe students initial responses to the product, while large-scale testing is conducted to measure the product's effectiveness in enhancing students understanding more comprehensively.

The researchers conducted a small-scale pilot study in the fourth-grade class at SDN Tambakaji 03, Semarang City, involving six students with varying levels of comprehension:

two with very proficient comprehension, two with proficient comprehension, and two requiring guidance. This small-scale pilot study was conducted to test the multimedia-based problem-based learning on a limited basis before implementing it on a large scale [38]. Subsequently, a large-scale trial was conducted following the small-scale trial of multimedia-based problem-based learning to identify its strengths, weaknesses, and effectiveness. This large-scale trial involved 22 fourth-grade students at SDN Tambakaji 03, Semarang City, excluding the 6 students who had already participated in the small-scale trial.

Evaluation

This evaluation phase is the final stage of the ADDIE development model, designed to analyze the data obtained from the pilot test. The purpose of this phase is to ensure the system's effectiveness and provide a basis for improvement [39].

Table 1. Pretest and Posttest Results

Action	Average	Improvement
Pretest	72.73	14.99
Postest	83.64	

The data in Table 1 show that student learning outcomes improved after using multimedia-based problem-based learning. In the pretest phase, the average student score was 72.7, with a highest score of 90 and a lowest score of 40. Meanwhile, after using Multimedia-based on Problem-Based Learning in the learning process, the average post-test score increased to 83.6, with a highest score of 100 and a lowest score of 50. It can therefore be concluded that there was a 14.99% increase in the average score after the use of multimedia-based problem-based learning on the topic of energy transformation in the large-scale trial.

Feasibility of Multimedia-based Problem-Based Learning

Multimedia-based on Problem-Based Learning was evaluated to determine its suitability for the learning process [40]. The evaluation included validation by subject-matter and media experts, as well as feedback from teachers and students.

Table 2. Expert Validator Results

Expert	Presentage	Criteria
Subject Matter Expert	95%	Very Suitable
Media Expert	96%	Very Suitable

Based on the data in Table 2, the assessment by the content validators of the Multimedia-based on Problem-Based Learning received a total score of 57 out of a maximum of 60, with a feasibility rate of 95%. Meanwhile, the media validators' assessment yielded a total score of 77 out of 80, with a feasibility rate of 96%. These results indicate that the Multimedia-based on Problem-Based Learning developed is highly suitable for use in the learning process.

The expert evaluation of the material consisted of four aspects, namely 1) Material relevance; 2) Content and language; 3) Material usefulness; and 4) Practicality of use. In the aspects of material suitability and practicality of use, the material received the maximum score with the criterion of “highly suitable.” These results indicate that the material presented aligns with the learning outcomes and objectives, is systematically organized, and is relevant to the characteristics of elementary school students, thereby helping students understand the material more effectively. The use of media that aligns with learning objectives can enhance students' ability to understand the material, as such media meets students' needs in the learning process [41].

The media validator’s assessment consists of four aspects, namely 1) visual design; 2) audio and video; 3) animation; and 4) ease of use of the media. In terms of visual design, audio and video, and ease of use, the media received the highest score, “highly satisfactory”. These results indicate that Multimedia-based on Problem-Based Learning features an attractive interface, with appropriate selection of colors, images, fonts, audio, and video that facilitate students use of Multimedia-based on Problem-Based Learning and supports the functions of educational media, namely 1) Attention Function, attracting attention and directing students to focus on the material being studied; 2) Affective Function, evoking students emotions and attitudes through visual illustrations; 3 Cognitive Function, helping students remember information or messages contained in the material; 4) Compensatory Function, assisting students who require guidance in receiving the material and understanding the learning content in text form [42], so that Problem-Based Learning-based Multimedia can provide a more engaging and interactive learning experience for students.

Table 3. Teacher and Students Response Results

Respondents	Presentage	Criteria
Teacher	97.5%	Very Suitable
Students	97%	Very Suitable

This is supported by Table 3, which shows that the teacher response received a feasibility rating of 97.5% and the student response received a feasibility rating of 97%, both meeting the criteria of “highly feasible” indicating that the multimedia-based problem-based learning is suitable for use in teaching natural science on the topic of energy transformation for fourth-grade students. The evaluation of teacher and student questionnaire responses consists of three aspects, namely 1) Media presentation, 2) Content, and 3) Media usage. The high response rates from teachers and students indicate that multimedia-based Problem-Based Learning needs and can be effectively utilized in the learning process [43].

The Effectiveness of Multimedia-based Problem-Based Learning

To determine the effectiveness of multimedia-based problem-based learning, the researcher used SPSS software version 25 to conduct a normality test, a paired-sample t-test, and an N-Gain test [44].

Table 4. Normality Test Results

Action	Sig	Criteria
Pretest	0.206	Normal
Postest	0.124	Normal

Based on table 4, and the results of the normality test, the decision criteria from the Shapiro-Wilk test are as follows: 1) If the significance value > 0.05, then the research data is normally distributed; 2) If the significance value < 0.05, then the research data is not normally distributed. The results of the normality test show that the pretest significance value is 0.206 > 0.05 and the posttest significance value is 0.124 > 0.05, indicating that the data are normally distributed. Therefore, it can be concluded that the results of both the pretest and posttest data on the small and large scales are normally distributed because they are > 0.05.

Table 5. Paired Sample t-Test Results

Action	Mean	Improvement	Sig
Pretest	72.73	10.90	0.000
Postest	83.64		

Based on Table 5, the results of the Paired Sample Test indicate an increase of 10.90, with an average pretest score of 72,73 and an average posttest score of 83,64. Therefore, using Multimedia-based on Problem-Based Learning improved student learning outcomes. The significance value is 0.000, which is below the criterion of 0.05, so H0 is rejected. As the (2-tailed) significance is 0.000 < 0.05, H0 is rejected, and Ha is accepted, indicating an improvement in the learning outcomes of fourth-grade students at SDN Tambakaji 03 after using Multimedia-based on Problem-Based Learning.

Table 6. N-Gain Results

Action	Mean	Improvement	N-gain	Criteria
Pretest	72.73	10.90	0.4493	Sedang
Postest	83.64			

Based on Table 6, the results of the N-Gain test indicate an increase in pretest and posttest scores of 0.4494, corresponding to a 10.90-point increase, which falls within the moderate range. The moderate N-Gain score is attributed to several factors, including students' readiness to learn, their ability to access technology, and their diverse characteristics and learning styles. Elementary school students are in the concrete operational stage of cognitive development, as they are in the 7-11-year-old age range. At this level, students prefer to play, move around, work in groups, and engage in hands-on activities [45].

Elementary school students have a wide variety of learning styles, including 1) Visual, students find it easier to understand the material through images, animations, and videos; 2) Auditory, students find it easier to understand the material through oral explanations, discussions, audio, and educational videos; 3) Kinesthetic, students find it easier to understand material through practical activities, exploration, simple experiments, and direct involvement in the learning process [46]. Multimedia-based on Problem-Based Learning has facilitated these three learning styles by presenting material in the form of images, animations, audio, video, problem-solving discussion activities, simple experiments, and an interactive snake-and-ladder edugame that involves students' active participation in learning.

The diverse characteristics of students can also lead to differences in their ability to understand the material presented [47]. Readiness to learn can be fostered through motivation and by encouraging students to actively engage in the learning process. In addition, students' readiness to access technology can be supported by the availability of adequate devices and internet networks, as well as teacher guidance in using multimedia-based problem-based learning.

Theoretically, the findings of this study are consistent with constructivist theory, which holds that knowledge is actively constructed by students through experiences, exploration, and interaction with the learning environment. The application of Problem-Based Learning in multimedia enables students to actively engage in identifying problems, conducting investigations, processing information, and developing an understanding of the concept of energy transformation based on their learning experiences [48].

The development of Multimedia-based Problem-Based Learning is effective in improving fourth-grade students' learning outcomes on the topic of energy transformation at SDN Tambakaji 03 in Semarang City. Learning media plays a crucial role in enhancing the effectiveness and efficiency of the learning process by providing a more concrete and meaningful learning experience. The “Snakes and Ladders” edugame presented in the Multimedia, based on Problem-Based Learning, facilitates engaging, meaningful, and challenging learning. Learning media serve as a tool that plays a vital role in conveying information from teachers to students to support the achievement of learning objectives [49].

Conclusion

The results of the study indicate that the design of a Multimedia-based on Problem-Based Learning (PBL) program on the topic of energy transformation, which uses Canva to design the cover page, user guide, activity guide, learning activities, glossary, bibliography, and developer profile and which was further developed and enhanced with an interactive Snakes and Ladders edugame through Genially, aimed at improving student learning outcomes through interactive, engaging, and contextual learning presentations. The content expert feasibility results were 95%, and the media expert results were 96%, both in the "highly feasible" category, supported by the teacher response questionnaire at 97.5% and the student response questionnaire at 97%, both in the “highly feasible” category. The effectiveness results of the Multimedia-based on Problem-Based Learning are demonstrated by a significant increase in pretest and posttest scores from 72.7 to 83.6 (a difference of 10.90), supported by a paired-samples t-test result of 0.000 < 0.05 and an N-Gain test result of 0.4439 (moderate criterion). The findings of this study suggest that Multimedia-based Problem-Based Learning can serve as an alternative teaching tool for teachers seeking to implement technology-based instruction that is more interactive, contextual, and student-centered. Integrating problem-solving activities with multimedia, including interactive edugames, can help teachers create more meaningful learning experiences and foster students' critical thinking skills in line with the demands of 21st-century learning. Thus, the Multimedia-based on Problem-Based Learning in energy transformation is declared to have been successfully developed, highly feasible, and effective in improving

learning outcomes on energy transformation for fourth-grade students at SDN Tambakaji 03 in Semarang City.

Author's Contribution

Y. A. Ghumaisha: Played a role in the product development process, research data processing, and the preparation of the article as the lead author.
A. E. Andriani: Contributed to the preparation and revision of the research findings.

Acknowledgements

We would like to thank the Elementary School Teacher Education Program, Faculty of Education and Psychology, State University of Semarang. We would also like to thank Ms. Aldina Eka Andriani, S.Pd., M.Pd., as our advisor, for her guidance, direction, and motivation. Thank you to my parents for their prayers, care, support, and love. Thank you to the principal, teachers, staff, and all students of SDN Tambakaji 03 for the opportunity, cooperation, and support provided to the researcher during this study.

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