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Integrating Articulate Storyline into Problem-Based Learning to Enhance Students' Conceptual Understanding

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Abstract: Low conceptual understanding in physics remains a recurring problem in secondary education, particularly because learning is often dominated by conventional methods. Although the Problem-Based Learning (PBL) model can promote critical thinking, its potential is not maximized without the support of interactive media. This study aims to determine the effectiveness of integrating Articulate Storyline into PBL as a strategy to enhance students' conceptual understanding of physics. This quasi-experimental research employed a non–equivalent control group pretest–posttest design, involving 50 tenth-grade students at SMAN 1 Labuhan Haji Barat, South Aceh, Indonesia. Class X IPA 1 (25 students) served as the experimental group, while Class X IPA 2 (25 students) acted as the control group, which was selected by the purposive sampling technique. Instruments consisted of a two-tier concept test and a student response questionnaire. Data were analyzed using N-Gain, an independent t-test, and qualitative categorization of conceptual understanding. The results showed that the experimental group achieved a higher N-Gain of 0.52, categorized as medium, compared to the control group of 0.26, which was categorized as low. An independent t-test revealed a significant difference between the two classes with an alpha value of 0.05. Qualitative analysis revealed a significant shift in students' conceptual categories, as the number of students in the "not understanding" and "misconception" groups decreased. In contrast, those in the "understanding concept" category increased substantially. Moreover, 91.2% of students responded positively to the use of Articulate Storyline, particularly appreciating its visual simulations, structured learning flow, and interactive quizzes. Integrating Articulate Storyline into PBL effectively enhances students' conceptual understanding and engagement in physics. This synergy provides empirical evidence that technology-enhanced PBL not only improves learning outcomes but also reduces misconceptions and fosters more meaningful learning experiences.

Keywords: articulate storyline, conceptual understanding, problem-based learning.

▪ INTRODUCTION

The 21st century's explosive growth in information and technology has had a significant impact on education. The teacher-centered learning approaches must give way to student-centered learning approaches in light of current educational practices (Mu'minah, 2021; Mardhiyah et al., 2021). Many students still find it challenging to grasp fundamental ideas in the context of physics education because traditional teaching strategies, like textbook summaries and repetitive problem-solving, frequently dominate the learning process with little interaction or use of cutting-edge media (Arafah, 2020; Afifah, 2020; Pradina & Yuliani, 2020). The scientific field of physics uses mathematical models to explain natural phenomena (Liza, 2021). On the other hand, students often struggle to understand physics due to its abstract nature. Students must have a conceptual understanding in order to apply physics concepts in practical settings (Nazarudin, 2014).

Low conceptual understanding has been linked to several factors by previous research, including teachers' limited capacity to effectively present concepts and the

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absence of pertinent learning contexts (Afifah, 2020; Syaifi & Murwitaningsih, 2022). To address this issue, teachers are encouraged to employ contextual and interactive learning models, such as Problem-Based Learning (PBL). PBL prioritizes real-world issues as springboard for education, encouraging critical thinking, teamwork, and student involvement (Sanjaya, 2016; Hotimah, 2020). PBL can also improve science learning outcomes and motivation, according to recent studies (Ina, 2021; Rieschka, 2020; Yusuf, 2022). While PBL has been proven effective, its impact can be amplified by the use of interactive digital media. International studies also show that PBL is much more successful at promoting conceptual change when aided by digital tools, such as simulations, virtual labs, and interactive multimedia (Zacharia & Olympiou, 2011; De Jong, 2013; Wu, 2020). Furthermore, the PBL instruction model can be applied to improve ICT literacy and problem-solving abilities while also effectively enhancing instruction overall (Nookhong, 2015). To foster the development of both experimental and conceptual competencies, laboratory experiences in physics education should incorporate both virtual and physical components (Becker, 2020). However, the majority of research on multimedia learning has concentrated on desktop environments that have animations. Students can better connect abstract physical theories with tangible experimental experiences by using interactive media, which offer visualizations and instant feedback.

Although there is encouraging evidence, the majority of research has concentrated on generic multimedia platforms or virtual labs, and Articulate Storyline's potential in physics education has not yet been fully realized. Different from traditional digital tools, Articulate Storyline supports dual-channel processing (visual and verbal) as proposed by multimedia learning theory by combining interactive simulations, branching scenarios, quizzes, and animations into a single structured module (Mayer, 2009; Mas'adah, 2019). Articulate Storyline's distinctive feature makes it a promising tool to enhance PBL by methodically guiding students through the problem-solving phases while also presenting physics concepts in an engaging manner. However, there are still a few empirical studies on how to incorporate it into PBL for physics, which highlights a gap that this study aims to fill. Animation and other interactive learning materials can be created with multimedia authoring tools like Articulate Storyline.

For example, Articulate Storyline is a multimedia authoring tool that can be utilized to create interactive learning content, including animation, audio, video, quizzes, and simulations (Bagus & Pujianto, 2023; Nurmarwa et al., 2022; Jazuli et al., 2023), which increased the students' conceptual understanding and interest in physics lessons, as well as the teacher's perception of its practicality and the positive student responses to its use during the learning process.

Physics learning at SMAN 1 Labuhan Haji Barat continues to face challenges in enhancing students' conceptual understanding, particularly on abstract topics such as force, motion, and energy. Formative assessment results indicate that the average score of students is still 58.7, which is below the KKM (70). The instructional model is still predominantly teacher-centered, relying heavily on lectures and rote exercises that do not involve active student engagement in the learning process. This is not an isolated case; similar issues are found nationwide and globally. Some studies in Indonesia have shown that students are often challenged by physics due to its abstract nature and because most physics learning is based on rote learning (Pradina & Yuliani, 2020). On a global scale, large-scale assessments such as PISA (OECD, 2019) consistently show that students in all countries struggle to apply physics concepts to real-world applications, highlighting the gap between theoretical knowledge and conceptual understanding. More importantly, international research has highlighted that traditional teacher-centered methods are ineffective in fostering higher-order thinking and problem-solving skills in science education (Bybee, 2020; Osborne & Dillon, 2008). These findings suggest that the issues at SMAN 1 Labuhan Haji Barat are indicative of the broader state of physics education and underscore the need to employ approaches such as PBL integrated with interactive digital media to foster meaningful learning.

As a result, many students tend to memorize formulas without grasping their physical meaning. This is in line with previous research that students tend to memorize rather than reason conceptually in physics learning (Pesman, 2010; Duit & Treagust, 2012), and survey data showing that 67% of students view physics as difficult and uninteresting, a trend reflected in wider research that physics is often considered one of the least engaging sciences at secondary school (OECD, 2019). Educational technology is used sparingly, and teachers rarely employ PowerPoint presentations or interactive tools, such as Articulate Storyline, that could present simulations, visualizations, and structured learning flows in a more engaging and contextualized way.

In the meantime, there is still a lack of integration of educational technology; teachers hardly ever use PowerPoint presentations and have never used interactive tools like Articulate Storyline, which could provide simulations, visualizations, and structured learning flows in a more contextualized and engaging way. Based on these gaps, this study explores how Articulate Storyline can be integrated into the PBL model to enhance students' conceptual understanding of physics at SMAN 1 Labuhan Haji Barat, considering the gaps identified in the results. The combination of PBL, a student-centered model of problem-solving, and Articulate Storyline, which offers interactive features, is expected to create a more engaging and meaningful learning environment.

This research aims to provide empirical evidence on how the integration of digital media within constructivist learning models can enhance students' conceptual understanding of physics, particularly in secondary education. To achieve this aim, the study addresses three key research questions: (1) To what extent does the integration of Articulate Storyline into PBL improve students' conceptual understanding of physics compared to conventional instruction? (2) How does this integration influence the shift in students' conceptual categories from misconception or no understanding to conceptual understanding? Moreover, (3) What are students' perceptions and responses toward the use of Articulate Storyline within the PBL framework in physics learning?. In line with the research questions, this study formulates the following hypotheses. The alternative hypothesis (*Ha*) states that the integration of Articulate Storyline into the Problem-Based Learning (PBL) model has a significant effect on improving students' conceptual understanding of physics compared to conventional instruction. Conversely, the null hypothesis (H_0) states that the integration of Articulate Storyline into PBL does not have a significant effect on students' conceptual understanding of physics. Statistical testing will determine whether *Ha* is accepted and H_0 is rejected, or vice versa, based on the obtained evidence.

▪ METHOD

Participants

The participants in this study were tenth-grade science students from SMAN 1 Labuhan Haji Barat, South Aceh, Indonesia. The population consisted of all tenth-grade students enrolled in the science program. The sample was selected using purposive sampling, with class X IPA 1 assigned as the experimental group and class X IPA 2 as the control group. Each had 25 participants (50 total). This study is limited by the use of purposive sampling, as it may compromise the generalizability of the results. The sample consisted of only two intact classes from one school. It is recommended that future research consider using random sampling across multiple schools to enhance external validity. Aside from the equivalent pretest scores, class X IPA 1 and class X IPA 2 were otherwise equivalent at the beginning of the study on several other factors: school records indicated that students' average physics grades from the previous semester were within 2 points of each other, indicating similar previous performance; and demographic data supplied by the school revealed the two classes were similar on gender, age, and socioeconomic status, among other factors.

Research Design and Procedures

This study used the Non-Equivalent Control Group Pretest–Posttest Design, a quantitative method with a quasi-experimental design (Sugiyono, 2012). Through the comparison of two intact groups that were not assigned at random, this design enabled the researchers to investigate the impact of an intervention. The independent variable in this study was the implementation of the Problem-Based Learning (PBL) model assisted by Articulate Storyline media. In contrast, the dependent variable was students' conceptual understanding of physics. The PBL model of instruction was used for both the experimental and control groups. The learning model was implemented in both groups over the course of four 90-minute sessions spread out over a month. The experimental group received PBL instruction enhanced with interactive Articulate Storyline modules during these sessions. In contrast, the control group underwent the same PBL phases using traditional resources, such as teacher-led PowerPoint presentations, printed worksheets, and textbooks.

The research procedures were carried out in several stages. Initially, the two-tier multiple-choice test instrument was developed and validated by experts in physics education to ensure its validity and suitability for assessing students' conceptual understanding. Reliability of the instrument was also assessed, with a Cronbach's alpha coefficient of 0.82. A pretest was then administered to both groups to measure initial understanding, and the learning treatment was implemented. The experimental group was taught using the PBL model with Articulate Storyline media, while the control group received the same PBL instruction without digital support. The experimental group was presented with Articulate Storyline modules with contextual problem scenarios, interactive simulations, branching exercises, and embedded quizzes, where students in small groups discussed the problem scenarios, predicted outcomes, and tested their reasoning by using the interactive features provided; the teacher facilitated group discussions and prompted deeper reflection on misconceptions revealed by the embedded quizzes. The control group also participated in PBL, but without digital support, using the physics textbook and printed handouts provided by the teacher to discuss problem scenarios. Additional explanations and PowerPoint slides were used to supplement the learning flow, including static text and images without interactive or simulation-based components. Following the intervention, both groups were given a posttest using the same instrument as the pretest. The final step was data analysis, which compared pretest and posttest results to determine the effectiveness of the PBL model integrated with Articulate Storyline in improving students' conceptual understanding of physics.

The digital learning media developed for the experimental group was created using Articulate Storyline, which included conceptual explanations, visual simulations, embedded videos, and reflection tasks to guide the Problem-Based Learning process. Figure 1 displays the main interface and content structure of the interactive learning module.

Figure 1. Main interface of the interactive physics module using Articulate Storyline, displaying content on renewable energy sources

Figure 2. Menu interface in articulate storyline showing access to embedded learning videos on renewable and non-renewable energy

Figure 3. Example of reflection questions presented at the end of the module to promote critical thinking about energy sustainability.

Instruments

The independent variable in this study was the implementation of the Problem-Based Learning (PBL) model assisted by Articulate Storyline media. In contrast, the dependent variable was students' conceptual understanding of physics. Both classes received instruction using the PBL model; however, only the experimental class was supported with interactive digital learning media developed using the Articulate Storyline software. To measure students' conceptual understanding, a two-tier multiple-choice test consisting of 10 items was used. The test was administered both before (pretest) and after (post-test) the treatment in both classes. Each question required students to select an answer and provide reasoning for their choice.

The test instrument used was the Two-Tier Test, with the scoring guidelines presented in Table 1 below. Student responses were then categorized into four levels based on the accuracy of their answers and reasoning, as shown in Table 2.

Table 1. Two-Tier test scoring guidelines

Criteria	Score
No answer	0
Answers more than one option	0
One correct answer in the second tier	0
One correct answer pada first tier	1
Two correct answers	2

Galatea & Sari (2020)

Table 2. Category of two-tier test answers on conceptual understanding

Answer Type	Description	Category
T-T	Students choose the correct answer and provide correct reasoning	Understanding concept
T-F	Students choose the correct answer but provide incorrect reasoning	Misconception

F-T	Students choose the wrong answer but provide correct reasoning	Guessing
F-F	Students choose both the wrong answer and incorrect reasoning	Not understanding

Oktavia et al. (2022)

The test instrument blueprint was developed based on the indicators of conceptual understanding proposed by Nafiati (2021), which include restating a concept, classifying, providing examples, presenting the concept in mathematical representation, and applying it, as shown in Table 3.

Table 3. Instrument blueprint for conceptual understanding

No	Indicator of Conceptual Understanding (Nafiati, 2021)	Operational Definition	Number
1	Restating a concept	Ability to express a physics concept in students' own words	2.4
2	Classifying	Ability to categorize phenomena or examples based on related physics concepts	1.7
3	Providing examples	Ability to give real-life or hypothetical examples that illustrate a physics concept	3.8
4	Presenting in mathematical representation	Ability to represent a physics concept through equations, graphs, or other mathematical forms	5
5	Applying the concept	Ability to use a physics concept to solve problems or explain new situations	6.9.10

Data Analysis

The data analysis procedure started with normality and homogeneity tests to check if the data fulfilled the assumptions for parametric testing, followed by an independent sample t-test to compare the post-test results between the experimental and control groups to assess whether there was a statistically significant difference in the conceptual understanding of the students in the experimental and control groups, and N-Gain to measure the effect of the learning model on students' conceptual understanding. The N-Gain was categorized as low ($g < 0.3$), medium ($0.3 \leq g \leq 0.7$), or high ($g > 0.7$) (Hake, 1999).

In addition to measuring conceptual understanding through tests, this study also collected data on students' perceptions of the learning experience using a response questionnaire. The student response questionnaire was analyzed to obtain students' perceptions regarding the influence of the PBL model assisted by Articulate Storyline on their conceptual understanding of physics. This analysis helps to describe the overall tendency of students' responses toward the implementation of the learning model.

▪ RESULT AND DISSCUSSION

The purpose of this study was to investigate the impact of the Problem-Based Learning model, supported by Articulate Storyline media, on students' conceptual understanding of physics. Pretest and posttest data were gathered from both the experimental and control classes, and normality and homogeneity tests were conducted for the data to meet the parametric assumptions, then an independent sample t-test was used to find the significance of the difference between the groups, N-Gain score was calculated for effectiveness of the intervention, and a student response questionnaire was analyzed for students' perceptions of the learning experience.

Normality Test

A normality test (chi-square (χ^2) test) was performed for the pretest and post test data for both the experimental and control classes, with $\alpha = 0.05$, sample size of 25 students, χ^2table = 11.07, F-table = 1.98, variance of experimental class = 79.17, variance of control class = 89.33, Fcount = 1.13, and variance is homogenous in both the pretest and post test scores.

For the experimental class, the chi-square values for the pretest were χ^2count = 6.86 ($p = 0.33$), and for the post-test, χ^2count = 4.05 ($p = 0.54$). Since both p-values are greater than 0.05, the pretest and posttest scores in the experimental class are normally distributed. Similarly, in the control class, the chi-square values for the pretest were χ^2count = 3.82 ($p = 0.57$), and for the post-test were χ^2count = 7.65 ($p = 0.26$). Both p-values are greater than 0.05, indicating that the pretest and posttest data in the control class follow a normal distribution.

Homogeneity Test

The homogeneity of variance test was conducted using the F-test to determine whether the variances of the experimental and control groups were statistically equal, both in the pretest and post-test scores. The test was conducted at a significance level of $\alpha = 0.05$, with an F-table value of 1.98. For the pretest, the variance of the experimental class was 79.17, while the control class had a variance of 89.33. The calculated F value was Fcount = 1.13, which is less than Ftable = 1.98. This indicates that the pretest data in both groups have homogeneous variance.

The F-test for homogeneity of variance was performed for the pretest and post test, to determine whether the experimental and control groups had statistically equal variances in both the pretest and post test scores ($\alpha = 0.05$, F-table = 1.98, Fcount = 1.13 for the pretest: Exp = 79.17, Ctrl = 89.33, Fcount < Ftable, same for the post test: Exp = 87.33, Ctrl = 89.33, Fcount < Ftable). It can be concluded that the assumption of homogeneity of variance is met for both pretest and post-test data, thus fulfilling one of the key assumptions for conducting parametric statistical tests such as the independent sample t-test.

Pretest and Posttest Results

The average pretest score in the experimental class was 45.20, and the posttest average was 78.20. Meanwhile, the control class had an average pretest score of 44.60 and a posttest average of 68.40. This suggests that both groups started at similar levels, but the experimental class experienced a greater improvement. Both classes started with nearly equal pretest scores, indicating similar initial conceptual understanding. However, after the intervention, the experimental class showed a higher increase in posttest scores compared to the control class. The higher posttest gain in the experimental class suggests that integrating Articulate Storyline media within PBL effectively facilitated a deeper conceptual understanding of physics learning.

The improvement was further analyzed using the N-Gain formula.The experimental class achieved an average N-Gain score of 0.52, categorized as medium, while the control class achieved an average of 0.26, categorized as low. The result implies that while PBL already contributes positively to learning outcomes, its impact becomes more pronounced when complemented by interactive digital media such as Articulate Storyline.

The findings of this study provide strong evidence that integrating the Problem-Based Learning (PBL) model with Articulate Storyline media significantly improves students' conceptual understanding of physics. The improvement was not only evident from the statistical analysis where the posttest mean score in the experimental group (78.20) surpassed that of the control group (68.40) but also from the medium N-Gain score (0.52) achieved by the experimental class compared to the control's low score (0.26). This aligns with prior research, which emphasizes that while PBL encourages critical thinking and collaborative inquiry (Ina et al., 2021), the inclusion of visual and interactive media enhances students' ability to internalize complex and abstract scientific concepts (Bagus & Pujianto, 2023).

However, not all studies report unequivocal benefits from adding interactive media to PBL. Meta-analytic evidence suggests that technology, on its own, yields at best modest average gains, and its impact depends strongly on pedagogy and the quality of implementation (e.g., task design, teacher facilitation). In particular, inquiry/PBL approaches with minimal guidance tend to underperform, whereas guided inquiry with scaffolds, feedback, and worked examples is reliably more effective; thus, interactive tools without adequate teacher mediation may not produce significant improvements in conceptual understanding (Alfieri et al., 2011; Lazonder & Harmsen, 2016; de Jong, 2023). Classic and recent work in physics education likewise cautions that interactive video/simulation environments do not realize their potential without an actively guiding teacher who clarifies tasks, addresses misconceptions, and orchestrates group processes (Escalada, 1995). Large-scale syntheses of educational technology also indicate small to moderate overall effects, emphasizing that instructional quality not the medium alone explains most learning gains (Tamim et al., 2011; Schmid et al., 2014). Taken together, these findings suggest that the effectiveness of integrating Articulate Storyline into PBL is conditional on sufficient scaffolding and teacher guidance during problem exploration, discussion, and reflection, which aligns with the facilitative role implemented in the present study.

Hypothesis Testing

The hypothesis was tested using the independent sample t-test on the post-test data. The result showed that $t_{count} = 2.67$, $p = 0.01$ and $t_{table} = 1.677$ ($\alpha = 0.05$). Since $p < \alpha$ then the null hypothesis (H_0) was rejected, indicating a statistically significant difference in conceptual understanding between the experimental and control groups. These findings confirm that the PBL model integrated by Articulate Storyline had a significant positive effect on students' conceptual understanding.

Analysis of Students' Conceptual Understanding Categories

The improvement in conceptual understanding was also analyzed through students' two-tier test response categories. In the experimental class, the number of students classified as "understanding" (T-T) increased from 16 students (pretest) to 25 students (posttest). At the same time, those in the "not understanding" (F-F) category decreased from 3 to 0. The granular analysis of misconceptions across renewable energy concepts reveals notable shifts after the intervention.

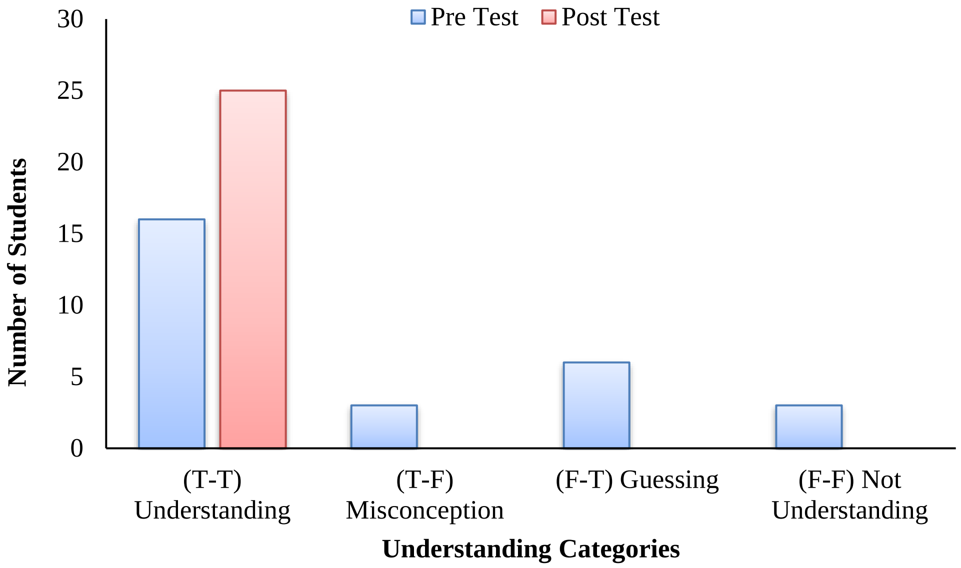

Figure 4. Comparison of students' conceptual understanding categories before and after PBL integrated articulate storyline

Table 4. Shift in students' misconceptions of renewable energy concept

Concept	Pretest – Misconception (n)	Posttest – Misconception (n)	Change
Solar Energy (PV)	8	2	–6
Wind Energy (Turbine)	7	2	–5
Hydropower	6	3	–3
Biomass Energy	9	5	–4
Environmental Impact	7	1	–6

Based on Table 4, the most significant decreases in misconceptions were observed in Solar Energy (–6) and Environmental Impact (–6). At the outset, many students held the mistaken belief that photovoltaic systems directly produce electricity or that renewable energy sources are entirely free from environmental consequences. On the other hand, the concept of Hydropower exhibited the smallest reduction (–3), indicating that some learners continued to have difficulty understanding how gravitational potential and water flow contribute to energy generation. Taken together, these results suggest that combining PBL with Articulate Storyline is particularly effective in addressing persistent misconceptions, especially for topics where visualization and real-world problem contexts are essential for comprehension.

Interestingly, the two-tier test results revealed a complete shift of students in the experimental group into the "T-T" (True–True) category after the learning intervention. This movement reflects not only their ability to select the correct answers but also their capacity to justify those choices with proper reasoning, that an important marker of genuine conceptual understanding (Hestenes et al., 1992). The disappearance of the other categories demonstrates how the use of interactive digital media can effectively close knowledge gaps and minimize misconceptions in physics learning.

Articulate Storyline is effective for independent learning because it is an interactive tool that increases students' motivation and engagement (Daryanes, 2023). In addition, the evaluation questions serve not only as feedback to assess students' understanding but also to identify possible misconceptions. Since the questions are designed based on competency achievement indicators, they help determine whether students have grasped the concepts correctly or are still experiencing misconceptions in the learning material.

This is particularly relevant, considering that, as Meißner (2016) highlights, problem-solving ability constitutes a crucial indicator of academic achievement in education, requiring students to explore problem contexts, process information, and coordinate multiple sources in order to generate accurate solutions. Misconceptions pose a significant barrier to this process, as they may lead learners to misinterpret problems or apply inappropriate principles. Therefore, the integration of Articulate Storyline not only enhances students' motivation and engagement but also provides a systematic mechanism for detecting and addressing misconceptions, thereby contributing to the development of more robust problem-solving skills.

Student Response Analysis

The data on students' responses to the influence of the Problem-Based Learning model assisted by Articulate Storyline were obtained through a student response questionnaire, the results of which are presented in Table 5.

Table 5. Students' responses to the problem-based learning model integrated articulate storyline on physics conceptual understanding

Indicator	Quantity	Percentage			
		Positive response		Negative response	
		Cont.	Exp.	Cont.	Exp.
I	4	91.2%	88.8%	77.2%	41.6%
II	4	84%	86.2%	48.8%	44.8%
III	4	95.2%	96.8%	34.4%	22.4%
IV	4	84.8%	92.8%	48.8%	32%

The questionnaire results revealed that 91.2% of students in the experimental class responded positively to the use of Articulate Storyline. The instrument used in this study consisted of 20 items on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The items were constructed to evaluate three core aspects: (1) usability and visual appeal of the media, (2) support for conceptual understanding, and (3) impact on motivation and engagement. Content validity was confirmed through expert review by two specialists in physics education and one in instructional media, resulting in an average Content Validity Index (CVI) of 0.92, which reflects a high level of validity. Furthermore, reliability testing using Cronbach's alpha yielded a coefficient of $\alpha = 0.87$, indicating a high reliability.

Student feedback indicated that features such as visual animations, well-organized content, and interactive elements (e.g., quizzes and instant feedback) were particularly effective in enhancing their understanding of physics concepts, especially in abstract areas like force, motion, and Newton's Laws. Learners also reported increased motivation and sustained attention when lessons incorporated digital media. These results align with the findings of Rohmah et al. (2025), who emphasized that interactive media not only foster better conceptual understanding but also boost students' motivation and interest in learning.

Research has consistently demonstrated that interactive digital media can enhance students' mastery of physics concepts while also fostering greater interest in the subject (Liliana et al., 2020; Sriyani et al., 2022). In line with this evidence, the present study found that learners who participated in PBL combined with Articulate Storyline achieved significantly higher post-test outcomes than those in the control class. The integration of interactive features provides both visual support and practical engagement, which are crucial for activating students' cognitive processes when working with abstract physics material (Herwansyah & Johan, 2023).

Moreover, embedding Articulate Storyline within the PBL framework was shown to strengthen its overall effectiveness by creating dynamic and visually engaging learning experiences. As emphasized by Ina (2021), PBL produces stronger results when supplemented with digital tools that encourage inquiry and collaborative discussion. Well-designed media also contribute to reducing misconceptions and minimizing random guessing by presenting contextual simulations alongside structured scaffolding (Resbiantoro & Setiani, 2022). In this study, Articulate Storyline was purposefully integrated into each stage of the PBL cycle in the following ways: (1) Problem Orientation: Students were introduced to real-world, contextual situations such as issues related to renewable energy through the use of animated storyboards and branching narratives. These elements fostered a sense of authenticity and sparked learners' curiosity. (2) Problem Identification and Clarification: Within the storyline, the media incorporated guiding prompts and structured questions to facilitate problem identification and clarification. Short quizzes with instant feedback encouraged students to express their preliminary ideas while also recognizing gaps in their knowledge. (3) Self-Directed Learning and Exploration: Interactive simulations, such as visual demonstrations of how solar panels generate electricity or how turbines produce power, allowed students to experiment in a virtual setting. These tools helped them connect abstract principles with tangible visual representations. (4) Collaborative Discussion: Discussion activities and checkpoints were embedded into the storyline, prompting students to collaborate, share answers, and debate different perspectives. Teachers guided the process, while digital prompts served as scaffolds to support meaningful group inquiry. Solution Presentation and Reflection: The storyline featured branching assessments and summary slides that enabled students to test their solutions against alternative outcomes. Immediate feedback reinforced accurate reasoning, addressed misconceptions, and encouraged reflective thinking.

Through Articulate Storyline features such as animations, branching scenarios, quizzes, simulations, and structured feedback, it did not merely serve as a presentation tool but acted as an interactive environment that scaffolded students' inquiry process at each stage of PBL. Therefore, this study confirms that the synergy between inquiry-based models and multimedia-rich platforms can significantly enhance students' conceptual mastery. Moreover, this study reinforces the theoretical underpinnings of multimedia learning theory (Mayer, 2009), which posits that students learn more effectively from a combination of words and visuals than from words alone. In this case, Articulate Storyline, as an interactive digital tool, facilitates dual-channel processing by presenting visual simulations alongside verbal explanations, which enhances mental model construction in abstract topics such as physics. In Articulate Storyline, the features of animated simulations are synchronized with short narrations, reducing split attention and cognitive load. Visual elements, including the use of arrows and color highlights, were applied in energy transfer topics to help direct students' focus toward key processes. At the same time, interactive quizzes with instant feedback served to address errors promptly, reducing the likelihood of misconceptions being retained. Furthermore, branching scenarios were designed to deconstruct complex problems into manageable stages, enabling students to approach them step by step. This aligns with the findings of Ayu (2024) and Ratnaningsih (2024). Several scholars have emphasized that digital interactivity can enhance students' attention, improve knowledge retention, and increase learning motivation. When PBL is supported with media that encourage exploration and provide instant feedback, the classroom becomes a richer learning environment in which students move beyond passive information reception and take an active role in building their own understanding.

In summary, the findings suggest that although PBL provides a solid pedagogical foundation, its effectiveness in fostering conceptual mastery is significantly enhanced when supplemented with thoughtfully designed digital media. Beyond reinforcing earlier research (Manalu, 2022; Nurmarwa et al., 2022), this study also provides valuable practical insights for instructional practice: educators should consider integrating interactive tools into problem-based learning to bridge the gap between abstract theory and meaningful understanding. In practice, physics teachers can integrate Articulate Storyline into their lessons by matching the modules with particular topics, such as renewable energy or Newtonian mechanics, and using them as digital companions to problem-based learning in class. When setting up problem tasks, it helps to frame them in real-world contexts, such as asking students to design an energy solution for a rural village. The branching feature can then guide learners to explore different solution paths.

Good media design also matters. Teachers should keep the material clear and uncluttered, highlighting key ideas with visual cues such as arrows or color, and combine spoken explanations with animations to help students process information more effectively. Adding short interactive quizzes with feedback can further strengthen understanding and prevent misconceptions from taking root. These recommendations can serve as a guideline for educators and instructional designers aiming to maximize the effectiveness of PBL with multimedia integration.

Limitations and Future Research

This study is limited by its quasi-experimental design, the small sample size of only two classes, the short duration of the intervention, and its focus on a single physics topic (renewable energy). These limitations may impact the extent to which the results can be generalized and how they are interpreted over time. To strengthen future work, researchers are encouraged to use larger randomized samples, extend the length of the interventions, and apply the approach across different areas of physics to examine its wider relevance. It would also be valuable to integrate qualitative methods, such as interviews or classroom observations, to gain deeper insight into students' learning experiences.

▪ CONCLUSION

This study demonstrates that combining the Problem-Based Learning (PBL) model with Articulate Storyline not only enhances students' conceptual understanding of physics but also increases their engagement by transforming abstract ideas into interactive and accessible learning experiences. The novelty of this work lies in demonstrating how a multimedia-rich platform such as Articulate Storyline is still rarely applied in physics education, which can be systematically embedded into each stage of PBL to address misconceptions through contextual simulations and responsive feedback. Beyond confirming its statistical impact, the findings suggest a broader implication: when digital media are thoughtfully designed and aligned with constructivist principles, they can help shift physics learning away from rote memorization and toward deeper, more meaningful conceptual mastery. Future research should extend over longer periods and across diverse physics topics to test the durability of these results. Qualitative insights, such as those gained from interviews or observations, would also enrich our understanding of how students experience and respond to these approaches. Crucially, the effectiveness of tools like Articulate Storyline depends on their thoughtful integration into pedagogy, ensuring they deepen inquiry and understanding rather than function as superficial add-ons.

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