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E-comic physics development through PBL stages to improve students' nature of science

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Abstract. The 2019 TIMSS results revealed that Indonesian students' science achievement remains below the international average, reflecting low scientific literacy. This issue is partly attributed to conventional teaching methods that lack engagement and inquiry-based approaches. This study aimed to develop a digital learning medium, *e-comic physics*, based on Problem-Based *Learning* (PBL) to enhance elementary students' understanding of the *Nature of Science* (NoS). Field observations at UPT SDN 3 Sumberejo revealed that 73% of teachers had not yet adopted interactive digital media, underscoring the study's urgency. Employing a Research and Development (R&D) design with the Tessmer model, involving 60 students, the study used descriptive and inferential statistical techniques. The findings showed that the media was highly valid, very practical, and significantly effective, as evidenced by improved post-test scores and t-test results. The effect size analysis indicated a moderate to substantial impact on learning outcomes, confirming the media's pedagogical potential in promoting scientific reasoning. In conclusion, the *e-comic physics* is a feasible and innovative learning tool for primary science education. Further research is recommended to examine its long-term effectiveness across broader subject matter.

Introduction

Students in the twenty-first century must be able to think critically, solve problems, work together, and be technologically literate (Laili, 2025). This need necessitates engaging teaching strategies that promote students' active participation in the educational process. Every person has the fundamental right to education, which is essential for helping people reach their full potential by utilizing science and technology (Murni et al., 2024). Digital learning resources are now crucial for developing contextualized and timely learning experiences (Khotimah et al., 2021; Widana, 2020).

One of the essential competencies that must be developed from an early age is the Nature of Science (NoS), an understanding of the nature of science both as a product (concepts and theories) and as a process (through observation, experimentation, and scientific reasoning) (Chuene & Singh, 2024). Mastery of NoS plays a vital role in shaping a scientifically literate society that thinks critically and makes decisions based on scientific evidence (Listiani, 2023). However, the 2019 TIMSS survey revealed that Indonesian students scored only 397 in science, significantly below the international

average of 500 (TIMSS, 2019). This finding reflects the low level of scientific literacy, largely due to the conventional and minimally exploratory nature of current science learning approaches.

Science education should not only deliver content but also cultivate scientific thinking. Weak scientific literacy indicates the need for a learning approach that goes beyond mere information delivery and fosters active student involvement in scientific processes such as observing, inferring, and exploring natural phenomena. Problem-Based Learning (PBL) emerges as a promising approach because it presents real-world problems as the starting point for inquiry and collaborative problem-solving (Firdaus, 2025; Ernawati et al., 2024; Pramudiyanti et al., 2023). This approach aligns with Piaget's theory, which emphasizes the importance of direct experiences in the construction of knowledge (Magdalena et al., 2023; Widana, 2022).

One promising innovation in science education media is the e-comic physics, a digital interactive comic that presents physics concepts through visual storytelling. This medium is designed to help students grasp abstract concepts more easily through a combination of text, images, and contextual narratives. Research has shown that media like e-comic physics can significantly improve students' interest and understanding of science concepts (Laksmi & Suniasih, 2021). Its engaging visuals and contextual storytelling make abstract material more concrete and enhance students' learning experiences in a fun and meaningful way. These results align with other research highlighting the benefits of comics and e-comics in teaching science.

Numerous prior studies support the effectiveness of comic and e-comic media in science education. Hanifah & Mufit (2022) demonstrated that comic media enhance conceptual understanding, motivation, conservation attitudes, and thinking skills. Laksmi & Suniasih (2021) and Widana et al. (2021) stated that PBL-based e-comics are highly feasible for use. Priadi et al. (2023) found that inquiry-based science comics can improve character development and learning outcomes.

The urgency of this research is further supported by preliminary observations at UPT SDN 3 Sumberejo, Kemiling, Bandar Lampung. It was found that 73% of teachers have not yet used engaging digital media in the learning process. The methods employed remain conventional and are insufficient in facilitating the development of students' scientific thinking abilities. Initial test results showed a low understanding of NoS among students, particularly in aspects such as empiricism, observation, inference, and scientific creativity. The integration of the PBL approach with e-comic media enables students to actively engage in contextual and engaging learning that fosters critical thinking and problem-solving skills from an early age.

Based on the background above, the following are the study's research questions: (1) How realistic is the use of problem-based learning in e-comic media to enhance elementary school pupils' comprehension of the nature of science? (2) How useful is it for teachers and students to use the media during the learning process? (3) How well do elementary school pupils grasp the nature of science when using PBL-based e-comic physics media?.

Method

To improve primary school students' Nature of Science (NoS) competency, this project employed a Research and Development (R&D) strategy to develop an educational media product, an e-comic physics based on Problem-Based Learning (PBL). The development model adopted follows the Tessmer framework as referenced in Khoerunnisa et al. (2024), which consists of three main phases: preliminary research, prototyping stage, and assessment stage. These three phases are

systematically structured to ensure that the resulting product possesses theoretical validity, practicality, and effectiveness in real-world educational settings.

In the Prototyping Stage, media development followed Tessmer's formative evaluation, starting with a self-evaluation to produce the initial prototype. This prototype underwent several revisions through expert review, followed by one-to-one evaluation and small group evaluation, resulting in a fourth prototype deemed valid. The final prototype was tested in a field test involving fifth-grade students using a pretest-posttest control group experimental design (Khoerunnisa et al., 2024). The experimental group used the e-comic physics media, while the control group used conventional student textbooks.

The final stage, the Assessment Stage, included assessments of the media's feasibility, practicality, and effectiveness (Khoerunnisa et al., 2024). Subject matter experts, media experts, and language experts carried out the feasibility test to assess the content's correctness and comprehensibility. Practicality was measured through teacher and student questionnaires regarding ease of use. Effectiveness was determined through pretest and post-test scores to measure improvement in NoS understanding. The results of these three evaluations confirmed that the PBL-based e-comic physics is valid, practical, and successful for integrating science instruction in elementary schools.

The study was carried out at SDN 3 Sumberejo, Kemiling Subdistrict, Bandar Lampung City, in May 2025. The research subjects were fifth-grade students from classes VA and VB. Class VA was designated as the experimental group, receiving instruction using the PBL-based e-comic physics, while class VB served as the control group, using conventional comic media. The sampling technique was purposive, considering student characteristics and teacher readiness in each class. The total sample consisted of 60 students (30 from class VA and 30 from class VB) selected from a population of 115 fifth-grade students at SDN 3 Sumberejo.

Data were collected using test and non-test instruments (Ali Ibrahim et al., 2024). Questionnaires, which are non-test tools, were used to gather media reactions, evaluate the product by experts, and assess the requirements of teachers and students. The instruments were validated using product-moment correlation, and their dependability was evaluated using Cronbach's Alpha. Meanwhile, test instruments in the form of essay questions were used to assess students' NoS abilities before and after the learning intervention. The NoS indicators assessed included tentativeness, empiricism, theory and law, creativity, and observation and inference (Hogan & O'Flaherty, 2022).

The feasibility and practicality analyses were conducted descriptively by calculating the percentage of responses from experts, teachers, and students, using the following categories: very feasible/practical (81–100%), feasible/practical (61–80%), and so on. Effectiveness was analyzed quantitatively using the independent samples t-test, preceded by normality and homogeneity tests. The effect size of the media was also calculated using Cohen's d, with categories as follows: 0–0.20 (small), 0.21–0.50 (medium), 0.51–1.00 (large), and >1.00 (very large). The flowchart below illustrates the stages of developing the PBL-based e-comic physics to improve elementary students' Nature of Science understanding.

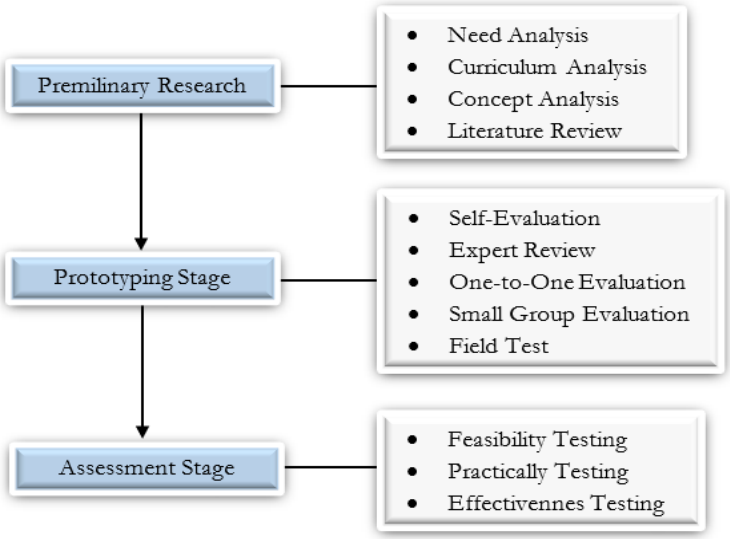

Image 1. Research Flow

The findings of this study are expected to produce an instructional media product that is both valid and practical, and that successfully enhances students' NoS skills. Through a problem-based approach and interactive digital media, this study makes a unique contribution to the creation of elementary-level science learning materials.

Results and Discussion

The findings of this study are presented descriptively by elaborating on three main aspects that served as the focus in the development of the media: feasibility, practicality, and effectiveness. These three aspects were evaluated to determine the extent to which the Problem-Based Learning (PBL) E-Comic Physics media can be optimally used in elementary school learning. The results include: (1) the feasibility of the PBL-based E-Comic Physics media, (2) the practicality of the media in the context of elementary education, and (3) the effectiveness of the media in enhancing students' Nature of Science (NoS) abilities. Each of these findings is presented systematically in the following sections.

Feasibility of the Problem-Based Learning-Based E-Comic Physics Media

Experts in language, media, and content participated in a validation procedure to determine the viability of the E-Comic Physics medium. The purpose of this validation was to ensure that, prior to field testing, the produced media met the feasibility requirements from multiple perspectives.

Table 1. Results of Content Expert Validation

Content Expert	Aspect	Score Obtained	Maximum Score	Percentage
Expert 1	Curriculum	70	75	93%
	Content Quality	71	75	95%
	Total	141	150	94%
	Criteria	Very valid, highly feasible, ready for use		
Expert 2	Curriculum	71	75	94%
	Content Quality	72	75	96%
	Total	143	150	95%
	Criteria	Very valid, highly feasible, ready for use		

Table 1 shows that the first expert gave a score of 90 out of 75 for the curriculum aspect (93%) and 71 out of 75 for content quality (95%), resulting in a total score of 141 out of 150 (94%). The second expert gave 71 (94%) for curriculum and 72 (96%) for content, totaling 143 (95%). Despite the discrepancy, especially in the curriculum aspect, both experts assessed the Problem-Based Learning-based E-Comic Physics media as "very valid and feasible for use." The average total score reached 84%, reinforcing the conclusion that the media meets general standards of content and curriculum feasibility.

These findings align with Rahmawati et al. (2024), who stated that learning media is considered feasible if it effectively supports the achievement of competencies and aligns with students' developmental stages. The media validated by two content experts in this study met these criteria through relevant curriculum content and accessible presentation. Within the PBL context, the media also supports the development of critical thinking and problem-solving skills (Havenga et al., 2023; Rohman et al., 2025; Purnadewi & Widana, 2023).

Based on expert validation, the Problem-Based Learning-based E-Comic Physics media is considered highly feasible in terms of both content and curriculum alignment. Although there were differences in scores across certain aspects, the media generally met the feasibility standards. These findings suggest that the media has strong potential to serve as an innovative alternative for enhancing physics concept understanding in an enjoyable, contextual, and PBL-aligned manner.

Table 2. Media Expert Validation Results

Media Expert	Aspect	Score Obtained	Maximum Score	Percentage
Expert 1	Media Visual Design	43	50	86%
	Accessibility	45	50	90%
	Total	88	100	88%
	Criteria	Very valid, highly feasible, ready for use		
Expert 2	Media Visual Design	45	50	90%
	Accessibility	46	50	92%
	Total	91	100	91%
	Criteria	Very valid, highly feasible, ready for use		

Table 2 shows that the first expert gave a score of 43 out of 50 (86%) for media visual design and 45 out of 50 (90%) for accessibility, resulting in a total of 88 (88%). The second expert gave 45 (90%) and 46 (92%), respectively, with a total of 91 (91%). Both experts assessed the Problem-Based Learning-based E-Comic Physics media as "very valid, highly feasible, and ready to use." The average feasibility score reached 85%, indicating that the media is well-prepared for instructional use.

This study also aligns with the research by Pawitra & Kusumadewi (2025), which found that interactive comics can significantly increase students' motivation and understanding through visual and narrative presentation. The E-Comic Physics developed in this study integrates visual storytelling and problem-based scenarios, effectively supporting the PBL approach. Involving two media experts with relevant backgrounds adds credibility to the validation process, and the results indicate that the media meet digital learning design standards.

According to the validation results provided by media experts, the E-Comic Physics media grounded in Problem-Based Learning is considered highly appropriate and valid for

implementation in elementary science instruction. While minor improvements are still needed in terms of accessibility, the media meets sufficient technical and visual criteria to support learning objectives and promote active student engagement.

Table 3. Language Expert Validation Results

Language Expert	Aspect	Score Obtained	Maximum Score	Percentage
Expert 1	Language Use	47	50	94%
	Criteria	Very valid, highly feasible, ready for use		
Expert 2	Language Use	40	50	80%
	Criteria	Very valid, highly feasible, ready for use		

Table 3 shows that the first language expert gave a score of 47 out of 50 (94%), while the second expert gave 40 out of 50 (80%). Both evaluations indicated that the media were "very valid, highly feasible, and ready to use," with an average validation percentage of 87%. This assessment reflects that the media meets high standards of linguistic quality in educational material development. Language in educational media must be clear, developmentally appropriate, and free from ambiguity, as emphasized by Widianita & Sujana (2024). Clear and concise language ensures that learners can easily understand and absorb the instructional content.

Furthermore, research by Tiara & Mubarok (2023) found that well-structured language in digital learning media significantly improves students' scientific literacy. The use of simple, effective, and age-appropriate language in this media contributes to improved comprehension and engagement.. With an average feasibility rating of 87%, the language used in the E-Comic Physics media is considered highly appropriate, communicative, and easily understood by elementary school students. These findings strongly indicate that the media is ready to be utilized as an effective instructional tool that supports learning objectives.

Practicality of E-Comic Physics Media in Elementary School Learning

This subsection explores the practicality of the E-Comic Physics media in the context of elementary science education. Practicality pertains to the media's user-friendliness, usability, and its capacity to support instructional goals effectively. The purpose of this evaluation is to assess user feedback to ensure that the media is not only visually engaging but also functional and seamlessly applicable within classroom settings.

Table 4. Practicality Test Results Based on Teacher Responses

No	Assessed Aspect	P1	P2	P3	Average
1	Content Relevance	90	80	79	83
2	Clarity of Content	80	70	85	78.3
3	Visual Appearance	90	95	93	92.6
4	Ease of Use	80	70	80	76.6
5	Integration with PBL Syntax	92	80	82	84.6
6	Student Engagement	75	90	90	85
7	Feature Completeness	80	94	75	83
8	Creative Presentation	80	90	85	85
9	Instructional Usefulness	70	90	80	80
10	Time Efficiency	90	70	80	80
Average Practicality Percentage					82.81 %

Based on Table 4, the practicality test of the E-Comic Physics media indicates that the media is easy to use and well-received by elementary school teachers. Assessments from three educators

(P1, P2, P3) across ten indicators showed consistently positive responses, with generally high average scores. The highest rating was in visual appearance (92.6%), suggesting that the design was attractive and suitable for young learners.

The aspect of integration with PBL syntax scored 84.6%, confirming the media's alignment with the problem-based learning approach. Instructional usefulness was also rated highly (85%), indicating the media's positive contribution to student understanding. However, ease of use (76.6%) and clarity of content (78.3%) received relatively lower scores, suggesting areas for improvement to enhance accessibility and user-friendliness. Overall, the average practicality score was 82.81%, categorizing the media as "very practical" and suitable for use in science education at the elementary level.

According to Nieveen in MacArthur et al. (2025), effective educational media must meet three criteria: validity, practicality, and effectiveness. The practicality aspect concerns how easily teachers and students can use the media in real learning settings. In this context, the results showed that teachers found the media visually appealing (92.6%), well-aligned with PBL syntax (84.6%), and beneficial for concept understanding (85%). These findings reinforce the media's support for interactive and meaningful learning processes.

The E-Comic Physics medium, based on PBL, has successfully satisfied the practicality requirements, as evidenced by the practicality outcomes and analysis. The media is not only easy to use for students but also supports fun, efficient, and 21st-century learning that emphasizes critical, creative, and collaborative thinking skills.

Table 5. Practicality Test Results Based on Student Responses

No	Evaluated Aspect	Percentage per Aspect
1	Ease of Use	22%
2	Coherence	30%
3	Engagement	42%
Average		94%
Criteria		Highly Practical

The practicality test results in Table 5 indicate that the E-Comic Physics media is highly practical for use in elementary school learning. The three core aspects assessed were ease of use (22%), coherence (30%), and engagement (42%), resulting in an average score of 94%. Although the individual percentages may appear small, they represent the converted weight scores of each indicator. Overall, students found the media easy to use, with no significant issues in navigation or features.

Students also perceived the media as consistently and structurally organized, following a logical flow aligned with their cognitive needs. The highest score in the aspect of engagement reflects the media's ability to create an enjoyable learning environment and boost student motivation. The total practicality score of 94% reinforces the conclusion that the E-Comic Physics is well-suited for elementary learners and effectively supports interactive, efficient, and meaningful science learning.

These results are consistent with those of Wulandari et al. (2024), who stated that effective learning media should meet the principle of practicality, namely, that it must be easy to use by students according to their age and cognitive development. Additionally, Afriyani (2025) highlighted how visually appealing media might improve students' comprehension and concentration on the subject matter.

Other research by Filjinan et al. (2022) supports this result, showing that interactive comic-based media is efficient and enhances student engagement in science learning. Their study found that comics not only clarify scientific concepts but also increase students' motivation and curiosity toward science topics.

It is clear from the practicality test and student assessments that the Problem-Based Learning E-Comic Physics medium is very useful for teaching in the classroom. Students reported that the media was easy to access, had a precise flow, and featured engaging visuals, which contributed to their learning motivation. These findings confirm that the media meet both technical and pedagogical practicality standards, making it an effective tool for delivering physics content in elementary schools.

Effectiveness of E-Comic Physics Media on Students' Nature of Science (NoS) Abilities

The effectiveness test aimed to measure the impact of the E-Comic Physics media on enhancing students' understanding, particularly in the aspect of Nature of Science (NoS). This study employed a quasi-experimental design involving two groups: Class A (experimental) used the e-comic media integrated with a Problem-Based Learning (PBL) approach. At the same time, Class B (control) received instruction through conventional methods. Comparing the two groups' pretest and post-test scores allowed for the measurement of effectiveness. The results are presented below.

Table 6. Effectiveness Test Results of E-Comic Physics Media

Group	Pretest	Posttest
Control Class	49.67	63.67
Experimental Class	59.00	81.33

Table 6 shows that the PBL-based e-comic physics media effectively enhanced students' understanding, especially in the Science aspect. The control group showed an increase from 49.67 to 63.67 (a gain of 14 points), while the experimental group increased from 59.00 to 81.33 (a gain of 22.33 points). The greater improvement in the experimental group indicates that the use of this media had a more substantial and more positive impact on science learning outcomes at the elementary level.

Table 7. Results of Normality Test

Tests of Normality				
		Kolmogorov-Smirnov[a]		
	Kelas	Statistic	Df	Sig.
NoS	Control Pretest	.131	30	.200*
	Control post-test	.137	30	.157
	Experimental Pretest	.135	30	.169
	Experimental post-test	.163	30	.172

The Kolmogorov-Smirnov approach was used to perform the normality test at a significance level of 0.05 in order to determine if the pretest and post-test results in the control and experimental classes were normally distributed. The findings demonstrated that every significance value (control pretest: 0.200; control post-test: 0.17) was higher than 0.05; experimental pretest: 0.169; experimental post-test: 0.172), indicating that all data followed a normal distribution. Therefore, the data met the assumption of normality, allowing further analysis using parametric tests such as the t-test.

Table 8. Results of the Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
NoS	Based on Mean	2.363	3	116	.075
	Based on Median	2.394	3	116	.072
	Based on Median and with adjusted df	2.394	3	112.377	.072
	Based on trimmed mean	2.368	3	116	.074

Both the experimental and control class data showed homogenous variances, according to Levene's Test of homogeneity. There were no discernible variations in variance across the groups, as indicated by the significance values from the several techniques (mean: 0.075; median: 0.072; trimmed mean: 0.074), all of which were higher than 0.05. Therefore, the data met the assumption of variance homogeneity required for parametric analysis.

Table 9. Results of the Independent Samples T-Test

Group Statistics					
	Class	N	Mean	Std. Deviation	Std. Error Mean
Nilai	Control Post-test	30	63.6667	18.47334	3.37276
	Experiment Post-test	30	81.3333	14.30055	2.61091

Students in the experimental class utilizing the problem-based learning e-comic physics media had an average post-test score of 81.33, according to Table 9. In contrast, the control class, which did not utilize the media, had an average score of 63.67. This shows a mean difference of 17.67 points, indicating that students' learning results were improved by using the instructional material. Furthermore, the experimental class's lower standard deviation (14.30) in comparison to the control class's (18.47) suggests that the experimental class's results were spread more equally.

Table 10. Results of the Independent Samples T-Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	T	df
Value	Equal variances assumed	3.793	.056	-4.142	58
	Equal variances not assumed.			-4.142	54.573

The significance value of Levene's Test is 0.056 (> 0.05), according to the Independent Samples T-Test results shown in Table 10, suggesting that the data have homogeneous variances. Therefore, the analysis refers to the "equal variances assumed" row. The significance value (2-tailed) of 0.000 indicates a significant difference between the post-test outcomes for the experimental and control classes. Therefore, compared to traditional training, the use of problem-based learning e-comic physical media has been shown to improve NoS students significantly.

Table 11. Independent Samples Test

		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower
Value	Equal variances assumed	.000	-17.66667	4.26525	-26.20449
	Equal variances not assumed	.000	-17.66667	4.26525	-26.21592

The Independent Samples T-Test findings in Table 11 showed a significant difference in mean scores between the experimental and control groups, with a significance value (2-tailed) of 0.000 (< 0.05). The experimental class outperformed the control class by a significant margin, as indicated by the mean difference of -17.66667. Thus, it is evident that using e-comic physical medium for problem-based learning improves NoS students'.

Table 12. Test Effect Size

Class	Cohens'd	Effect Size
Pretest – post-test Control Class	0.35	Modest Effect
Pretest – post-test Experiment Class	0.73	Moderate Effect
Postest (Control) – Postest (Experiment)	1.00	Strong Effect

Based on the effect size analysis presented in Table 13, the improvement in students' performance in the control group from pre-test to post-test yielded a Cohen's d of 0.35, which falls into the "modest effect" category. This suggests that the instructional approach employed in the control group produced only a limited enhancement in student ability. In contrast, the experimental group exhibited an effect size of 0.73 from pre-test to post-test (classified as a "moderate effect"), indicating that the Problem-Based Learning (PBL)–based E-Comic Physics media exerted a sufficiently significant influence on students' learning outcomes.

Additionally, a comparison of the experimental and control groups' post-test results showed an effect size of 1.00, which is classified as a "strong effect." This result suggests that, in comparison to the teaching strategies utilized in the control group, the instructional medium utilized in the experimental group significantly increased students' skills. Therefore, it has been demonstrated that using the E-Comic Physics medium, which is based on Problem-Based Learning (PBL), helps enhance student abilities, especially when it comes to establishing an understanding of the Nature of Science (Evi Yupani & Widana, 2023).

According to the research findings, students' comprehension of the Nature of Science (NoS) topics is improved by the E-Comic Physics medium, which is based on Problem-Based Learning (PBL). The experimental group's noticeably higher post-test results than those of the control group serve as proof of this. These findings are in line with Mayer's (2021). Multimedia Learning Theory suggests that combining text and graphics can help students develop better knowledge through visually oriented media, such as comics. This dual-channel presentation delivers information in an engaging and cognitively accessible format, thereby facilitating more effective learning.

Effectiveness-wise, the Independent Sample T-Test findings showed a statistically significant difference in learning outcomes between the experimental and control groups, with a significance value of 0.000 ($p < 0.05$). This finding is further supported by the study conducted by Ribawa et al. (2024), which demonstrated that problem-based interactive digital media significantly enhances elementary students' understanding of science concepts and their scientific attitudes compared to conventional instructional methods.

In addition, the effectiveness of the media is also reflected in the effect size analysis. The Cohen's d value for the experimental group was 0.73, indicating a moderate effect, while the control group recorded a lower value of 0.35, categorized as a modest effect. The comparison of post-test scores between the two groups yielded an effect size of 1.00, which falls within the strong effect category. This implies that the E-Comic Physics media not only demonstrated statistical significance but also had a substantial practical impact on improving learning outcomes. These findings are consistent with Bailey et al. (2022), who stated that an effect size above 0.40 indicates a meaningful impact on learning, with values exceeding 0.80 considered high. Similarly, a study by Khotimah & Hidayat

(2022) found that the use of interactive comics in science education resulted in a high effect size on students' conceptual understanding. Therefore, this media has been proven effective in supporting science learning grounded in the Science framework.

Based on the overall findings, it can be concluded that the Problem-Based Learning (PBL)–based E-Comic Physics media is effective in enhancing students' understanding of the Nature of Science (NoS) concepts. This conclusion is supported by statistical analyses, which reveal a significant difference in learning outcomes between the experimental and control groups, as well as effect size values that indicate a moderate to substantial impact on student achievement. The Cohen's d value of 0.73 in the experimental group and 1.00 in the post-test comparison between groups demonstrates that this media is not only theoretically effective but also exerts a tangible, practical influence on science learning processes at the elementary school level.

Conclusion

Given that it has been demonstrated to be legitimate, useful, and successful in improving students' comprehension of the Nature of Science (NoS) component, the research findings support the conclusion that problem-based learning e-comic physics media is a viable and creative substitute for science instruction in elementary schools. This media presents learning content engagingly and contextually through the integration of text, visuals, and problem-solving activities that promote active student engagement. Nevertheless, this study has many drawbacks, such as a small sample size and a narrow emphasis on a specific learning issue. To gain a more comprehensive understanding of the media's impact on learning outcomes, future studies are recommended to examine its effectiveness over a longer period and in a broader range of learning contexts.

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