Improving Significantly: Enhancing Elementary Science Literacy through STEM-PjBL Web-Based Learning Media

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Abstract: This study developed B-Science, a STEM-PjBL web-based learning medium designed to improve fifth-grade students' science literacy on the human digestive system and water cycle. The research employed Research and Development using the Hannafin and Peck model, consisting of need assessment, design, and development–implementation phases. The participants were 31 fifth-grade students at SDN Balimester 06, East Jakarta. Data were collected through expert validation, student response questionnaires, and pretest–posttest science literacy tests. Results showed that material, language, and media validation reached 90.75%, indicating very feasible quality. Student trials also produced highly positive responses above 92%. The effectiveness test showed normal data distribution, a significant difference between pretest and posttest scores, and a high N-gain of 0.76. These findings indicate that B-Science is valid, practical, and effective for strengthening elementary students' science literacy through interactive visualization and structured project-based learning. It also supports collaborative inquiry and self-paced access via mobile devices and browsers.

Abstrak: Penelitian ini mengembangkan B-Science, media pembelajaran berbasis web STEM-PjBL untuk meningkatkan literasi sains siswa kelas V pada materi sistem pencernaan manusia dan siklus air. Penelitian menggunakan metode Research and Development dengan model Hannafin dan Peck yang meliputi tahap need assessment, design, serta development-implementation. Subjek penelitian adalah 31 siswa kelas V SDN Balimester 06, Jakarta Timur. Data dikumpulkan melalui validasi ahli, angket respon siswa, serta tes literasi sains pretest-posttest. Hasil menunjukkan validasi materi, bahasa, dan media mencapai 90,75%, sehingga berkategori sangat layak. Uji coba siswa juga menunjukkan respon sangat positif di atas 92%. Uji efektivitas menunjukkan data berdistribusi normal, terdapat perbedaan signifikan antara skor pretest dan posttest, serta nilai N-gain 0,76 yang termasuk kategori tinggi. Temuan ini menunjukkan bahwa B-Science valid, praktis, dan efektif untuk memperkuat literasi sains siswa melalui visualisasi interaktif dan pembelajaran berbasis proyek yang terstruktur serta mudah diakses melalui perangkat seluler untuk mendukung pembelajaran mandiri dan kolaboratif secara fleksibel.

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A. Introduction

The development of the twenty-first century has brought major changes across many aspects of life and requires individuals to master a range of skills in order to adapt, including in science and technology. Traditional learning methods that rely solely on memorization and standardized tests are no longer sufficient to prepare students for future challenges. Therefore, skills that help students become more selective, adaptive, and responsive to change need to be developed from an early age (Shana, 2024). One of the most essential skills is science literacy, which enables learners to apply knowledge to ask questions, build new understanding, provide scientific explanations, and draw conclusions based on scientific evidence.

Developing science literacy from elementary school is important because it helps students view science as knowledge for all people and prepares them to think logically, critically, creatively, and collaboratively, while also improving communication skills (Sidabutar & Sembiring, 2023; Kutlu-Abu et al., 2024). Science literacy should be continuously strengthened to improve the quality of learning, learning outcomes, and students' overall understanding. However, in practice, science literacy is still not the main focus of instruction, and many students continue to struggle in understanding scientific concepts and applying science principles to real-world problems.

The situation in the field shows a concerning picture. Based on the 2022 Programme for International Student Assessment (PISA), Indonesia ranked 67th out of 81 participating countries in science, with an average score of 383, which also declined compared to the 2006 achievement (Setyorini et al., 2022). A similar condition was found at SDN Balimester 06, where the average science summative score reached only 63.3. Students had difficulty explaining simple phenomena, were not accustomed to systematic observation, and tended to accept information without scientific verification (Roy et al., 2025). Learning also remained one-way, with media limited to textbooks, even though schools already had access to technological facilities such as projectors and smartphones (Rosiningtias et al., 2023).

Based on these conditions, meaningful technology-based learning media are needed. Web-based learning media can present material in a structured, efficient, up-to-date, and easily accessible format through smartphones. Abstract scientific concepts can be visualized through interactive animations and simulations, making them easier for students to understand while also providing practical and structured learning guidance without the need for paper or ink. In addition, the STEM-PjBL model (Science, Technology, Engineering, and Mathematics–Project-Based Learning) has been shown to improve science literacy, support interactive learning, increase learning motivation, and foster creativity in elementary school students (Rahmadani et al., 2024). Web-based learning is also effective in reducing classroom boredom, can be accessed anytime and anywhere, and has been shown to be highly feasible as a learning medium (Pratami & Kholiq, 2024). The integration of web-based learning and STEM-PjBL becomes the basis for this study, as it is expected to make learning more interactive and flexible through real projects while maintaining science literacy as the main learning outcome (Ayu et al., 2021; Lee & Lee, 2025).

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Although STEM and PjBL have both been widely studied, most previous studies have examined them separately. Several studies have integrated STEM into elementary science learning, but they have not yet used an interactive web platform as the learning environment (Listiyana et al., 2023). On the other hand, web-based research for science literacy has generally focused on junior high and high school levels and has not structurally integrated the PjBL syntax into the platform (Ratri Shinta Wardhani, 2025). Thus, an important research gap remains: there is still no web-based platform that fully integrates STEM-PjBL as an active learning model to improve elementary school students' science literacy.

The novelty of this study lies in the integration of STEM-PjBL within a single web-based learning platform called B-Science, specifically designed for fifth-grade elementary school students. Unlike previous studies that used web platforms mainly as content repositories or implemented PjBL in offline settings, B-Science digitally supports the full PjBL syntax from video observation, question formulation, and project design to result presentation with achievement indicators aligned to the four domains of science literacy (Ratri Shinta Wardhani, 2025). This integration constitutes a scientific contribution that distinguishes the present study from previous research.

This study focuses on developing STEM-PjBL web-based science learning media to improve the science literacy of fifth-grade elementary school students on the topics of the human digestive system and the water cycle. Based on the identified research gap, this study addresses two research questions: What are the characteristics of STEM-PjBL web-based science learning media that are valid and feasible for teaching the human digestive system and water cycle to fifth-grade elementary school students?, and how effective is the STEM-PjBL web-based science learning media in improving the science literacy of fifth-grade elementary school students in both topics?. This study aims to produce STEM-PjBL web-based science learning media that is valid and suitable for use in teaching the human digestive system and water cycle, and to analyze its effectiveness in improving students' science literacy. Theoretically, this study contributes to the development of STEM-PjBL website-based media and provides a reference that can be adapted for other science topics. Practically, it enables self-paced learning, supports the visualization of abstract concepts through interactive animations and simulations, strengthens digital and science literacy, and helps teachers monitor student progress through dashboards and real-time automated assessments.

B. Method

This study employed a Research and Development (R&D) approach using the Hannafin and Peck model, which consists of three iterative phases: need assessment, design, and development and implementation. This model was selected because it allows continuous evaluation and revision in each stage, making it suitable for developing interactive learning media that must respond to learners' needs and classroom realities (Bolick et al., 2024). In this study, the development process was directed toward producing

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B-Science, a web-based STEM-PjBL learning medium designed to improve fifth-grade students' science literacy on the human digestive system and water cycle. The study followed the logic of meaningful technology integration for elementary science learning, as supported by previous studies emphasizing the importance of digital media, STEM-oriented learning, and science literacy development from early schooling (Shana, 2024; Sidabutar & Sembiring, 2023; Rahmadani et al., 2024).

The research was conducted at SDN Balimester 06, East Jakarta, with 31 fifth-grade students as the main participants. The students were selected using purposive sampling based on classroom readiness, availability of technology access, and the need to represent varied student abilities. In addition, expert validators were involved in the development process, consisting of material experts, language experts, and media experts. Their role was to evaluate the feasibility, accuracy, clarity, and usability of the product before it was implemented in classroom trials. The selection of this setting and participants was aligned with the identified need for more interactive science learning and with the school's existing technological facilities, which had not yet been optimally used in instruction (Rosiningtias et al., 2023).

The product developed in this study was B-Science, a web-based learning platform built using Nuxt JS for the front end, Nest JS for the back end, and MySQL as the database. The platform contains teaching modules, learning materials, instructional videos, project activities, practice exercises, and notifications. These components were designed to support the full syntax of STEM-PjBL so that students could move from observing and questioning to planning, creating, and presenting project outputs. This design reflects the view that web-based learning can make abstract science concepts more accessible through interactive visualization while also providing structured and flexible learning experiences (Ayu et al., 2021). The implementation of STEM-PjBL in a single integrated platform was intended to make learning more contextual, collaborative, and engaging for elementary school students.

Data were collected through several techniques, namely observation, interviews, questionnaires, and pretest–posttest tests. Observation and interviews were used in the need assessment stage to identify classroom problems, while questionnaires were used to analyze student needs and to measure responses during product trials. Expert validation instruments were used to assess the content, language, and media quality of the product. In addition, a science literacy test was developed for the pretest and posttest, based on four domains: knowledge, inquiry, thinking, and science-technology-society (STS). The instrument development and validation process followed the standards of science education assessment and learning media evaluation (Kraus, 2024).

The development procedure began with need assessment, in which classroom observation, teacher interviews, and student questionnaires were used to identify the lack of innovative media, limited learning resources, and students' low engagement in science learning. The second stage was design, during which storyboards, media flowcharts, learning scenarios, and validation instruments were prepared. The third stage was development and implementation, during which the prototype was revised after expert

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review and then tested through one-to-one, small group, and field trials. These gradual trials were intended to measure both practicality and student acceptance before the media was used in a broader classroom setting. The process followed the logic of iterative product refinement recommended in R&D studies (Bolick et al., 2024).

Data analysis was carried out in several stages. First, feasibility scores from expert validation and student trials were calculated using percentage formulas and interpreted using feasibility criteria. Second, the validity of the science literacy instrument was tested using Aiken's V, while reliability was measured using Cronbach's alpha. Third, the effectiveness of the media was analyzed through normality testing, paired sample t-test, N-gain, and effect size analysis. Because the number of students was 31, a Shapiro–Wilk test would be more appropriate than Kolmogorov–Smirnov for testing normality, followed by a paired sample t-test at $\alpha = 0.05$ to determine differences between pretest and posttest scores. N-gain was used to determine the magnitude of learning improvement, while Cohen's d was calculated to show the practical impact of the intervention. This combination of analyses was used to determine whether B-Science was valid, practical, and effective in improving science literacy.

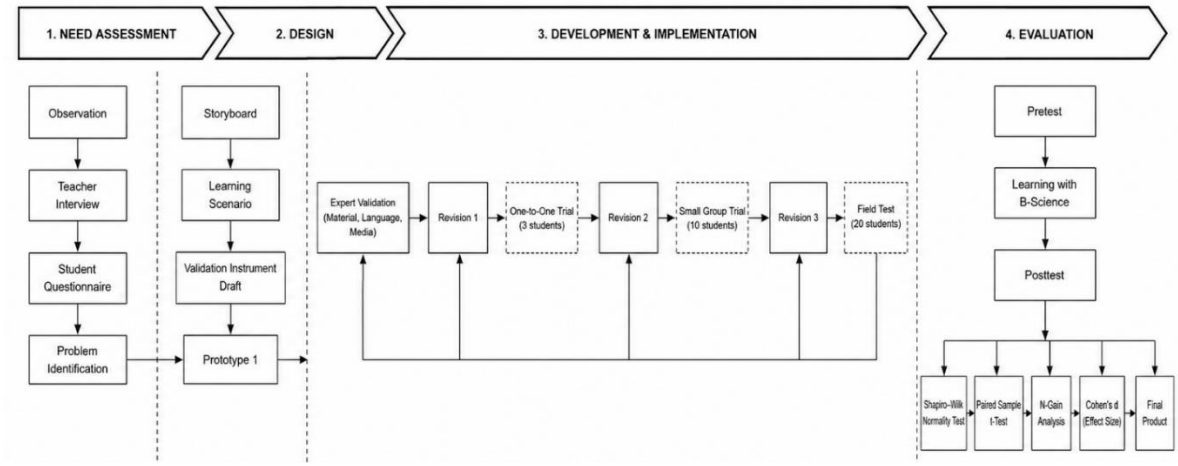

Figure 1. Research Flowchart of B-Science Development

C. Result

Need Assessment Results

The need assessment was conducted through classroom observations, teacher interviews, and student questionnaires at SDN Balimester 06, East Jakarta. The findings revealed that science learning was still predominantly teacher-centered and relied heavily on textbooks as the primary instructional resource. Students experienced difficulties in understanding abstract science concepts, particularly those related to the human digestive system and the water cycle. In addition, opportunities to develop science literacy skills through inquiry-based and project-based activities were limited.

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The questionnaire results showed that most students had access to smartphones and demonstrated a strong preference for learning through interactive digital media, such as videos and animations. Teachers also expressed the need for technology-supported learning resources that could facilitate active learning and improve students' science literacy. These findings indicate the necessity of developing an interactive STEM-PjBL web-based learning medium that can support meaningful science learning while utilizing the technological facilities already available in schools.

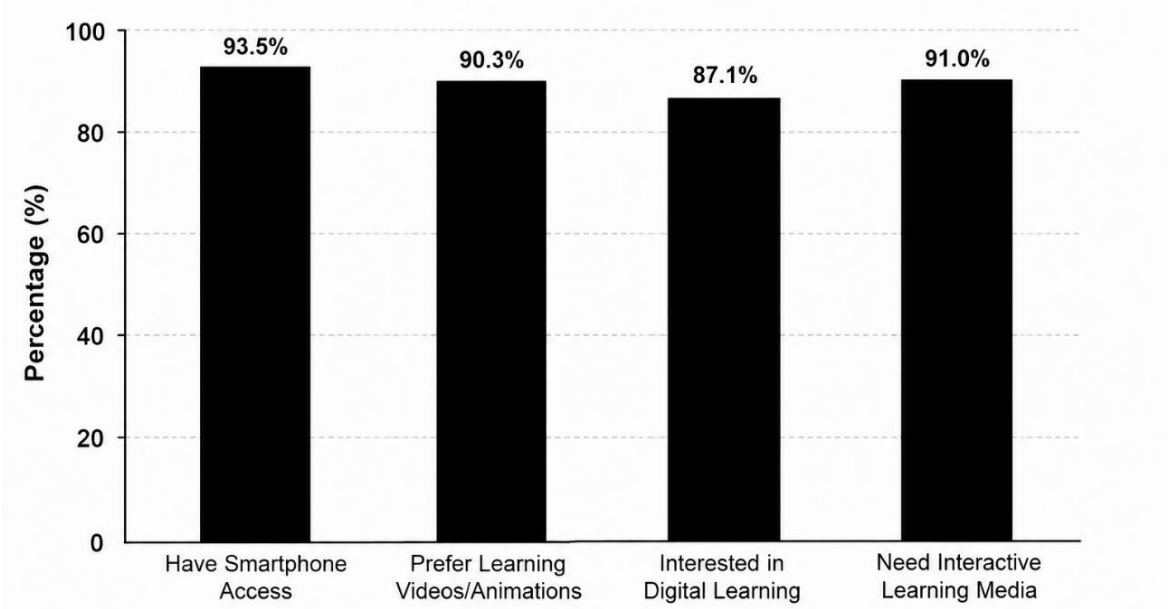

Figure 2. Results of Student Needs Analysis

Product Development Results

Based on the needs analysis, a web-based science learning medium named B-Science was developed using the STEM-PjBL approach. The platform was designed to facilitate science learning through interactive content, project-based activities, and science literacy-oriented assessments.

The development process followed the Hannafin and Peck model, consisting of need assessment, design, and development and implementation phases. During the design phase, a storyboard, learning flow, interface design, and validation instruments were prepared. The platform was then developed using Nuxt JS as the frontend framework, Nest JS as the backend framework, and MySQL as the database management system.

Table 1. Presents the Main Components of the B-Science Platform

Component	Description
Dashboard	User guidance and learning overview
Teaching Module	Learning objectives and instructional materials
Learning Materials	Human digestive system and water cycle content

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Component	Description
Learning Videos	Interactive science videos
Project Activities	STEM-PjBL-based project implementation
Practice Exercises	Science literacy-oriented questions
Notifications	Learning progress updates

The developed platform was designed to support the complete STEM-PjBL learning process, beginning with problem identification, information gathering, project planning, project implementation, and presentation of project outcomes.

Expert Validation Results

The feasibility of the developed media was evaluated by material experts, language experts, and media experts. Material validation assessed content accuracy, STEM-PjBL integration, science literacy alignment, and relevance to students' daily lives.

Table 2. Material Expert Validation Results

Aspect	Percentage (%)	Category
Content Feasibility	87.50	Very Feasible
Content Accuracy	93.75	Very Feasible
STEM-PjBL Integration	95.00	Very Feasible
Science Literacy	81.25	Very Feasible
Real-Life Relevance	100.00	Very Feasible
Average	86.00	Very Feasible

The material validation produced an average score of 86.00%, indicating that the content was highly appropriate for elementary science learning.

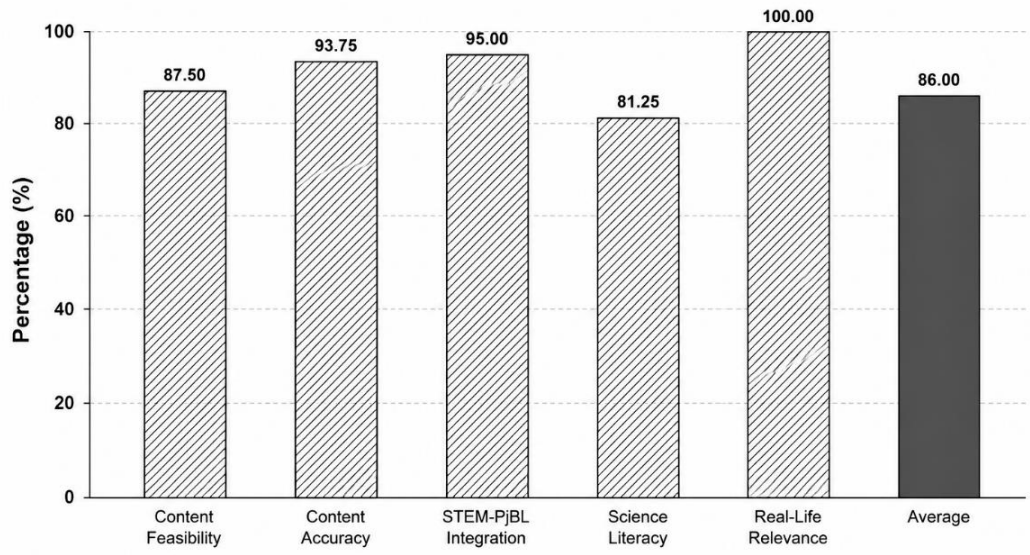

Figure 2. Results of Student Needs Analysis

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Language validation focused on readability, sentence structure, vocabulary, and grammar suitability for elementary school students. Language validation focused on readability, sentence structure, vocabulary, and grammar suitability for elementary school students.

Table 3. Language Expert Validation Results

Aspect	Percentage (%)	Category
Language Suitability	95.00	Very Feasible
Sentence Structure	85.00	Very Feasible
Vocabulary	95.00	Very Feasible
Grammar and Punctuation	95.00	Very Feasible
Average	**93.75**	**Very Feasible**

The language expert evaluation yielded an average score of 93.75%, confirming that the language used in B-Science was appropriate and easy for students to understand.

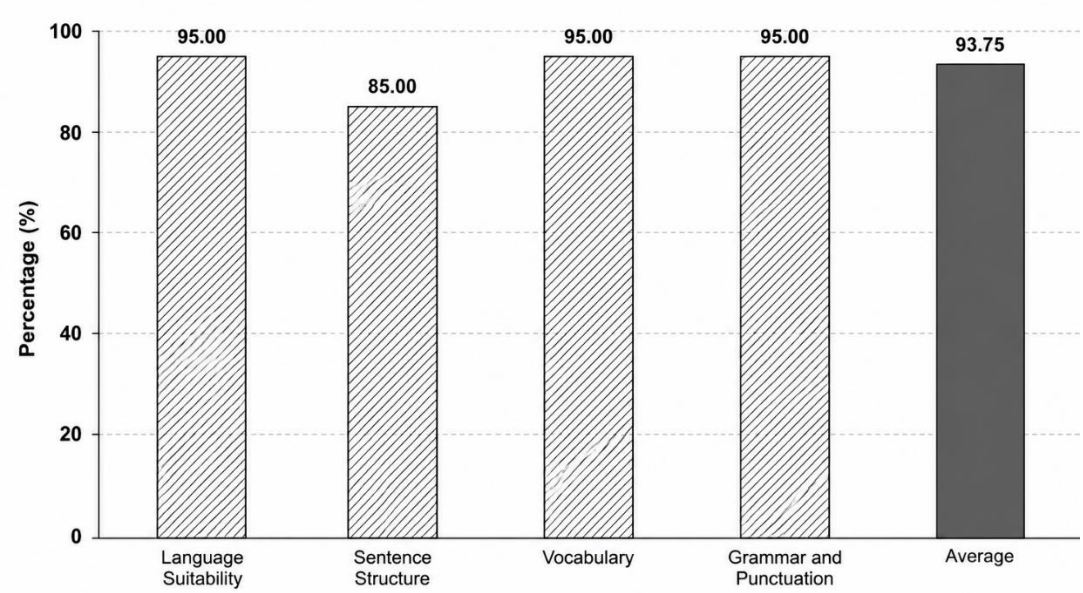

Figure 3. Language Expert Validation Results

Media validation examined interface design, navigation, interactivity, technical quality, and mobile compatibility.

Table 4. Media Expert Validation Results

Aspect	Percentage (%)	Category
Interface Design	95.00	Very Feasible
Navigation and Interactivity	90.00	Very Feasible
Technical Quality	95.00	Very Feasible
Mobile Compatibility	90.00	Very Feasible
Average	**92.50**	**Very Feasible**

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The average score of 92.50% indicates that the developed media met the criteria of highly feasible educational technology.

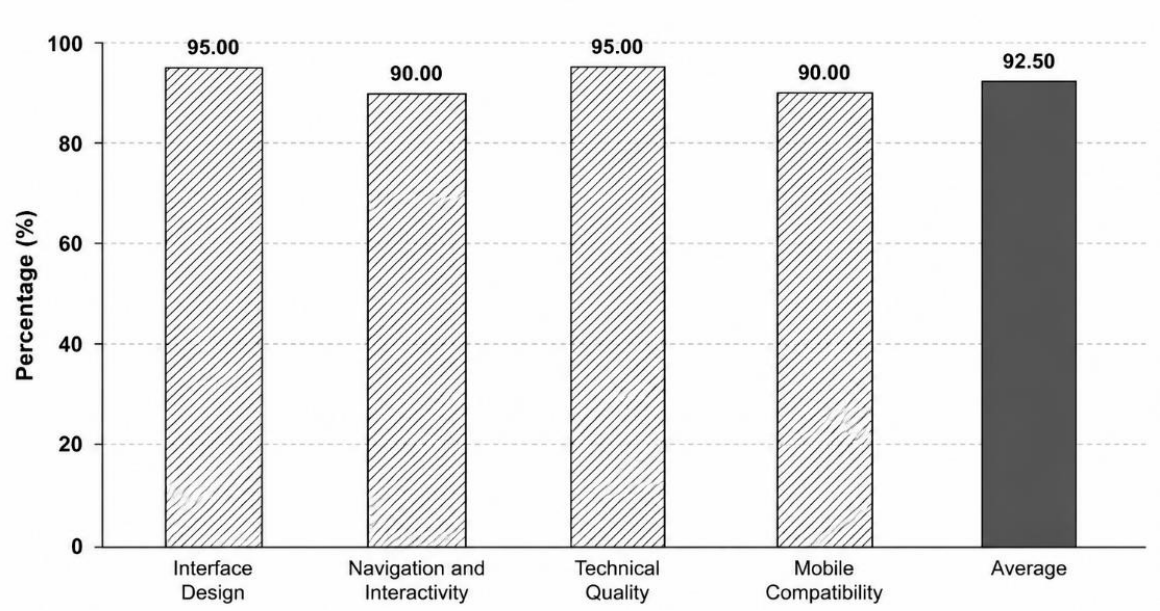

Figure 4. Media Expert Validation Results

The individual validation results indicate that B-Science meets the required standards in terms of content accuracy, language appropriateness, and media quality. The combined validation scores from all expert evaluations are presented in Table 5 to determine the overall feasibility of the developed learning media.

Table 5. Overall Expert Validation Results

Validator	Percentage (%)
Material Expert	86.00
Language Expert	93.75
Media Expert	92.50
Overall Average	**90.75**

Overall, the B-Science platform achieved an average validation score of 90.75%, indicating that it was highly feasible for classroom implementation.

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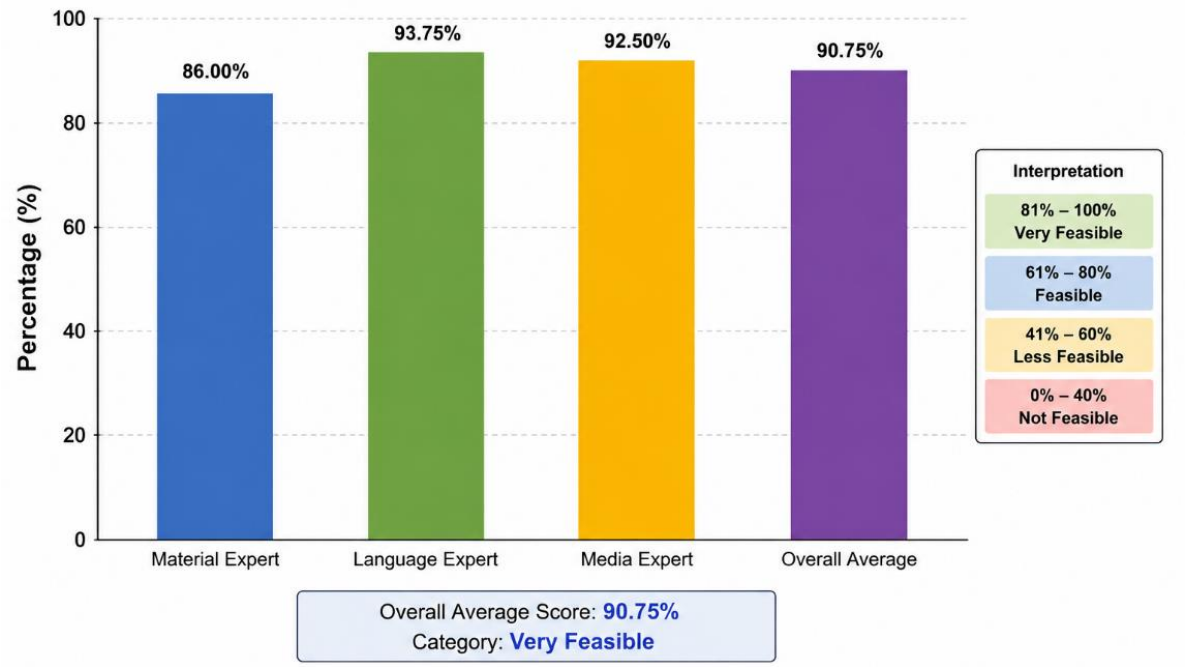

Figure 5. Overall Expert Validation Results

Product Trial Results

Following the expert validation stage, the revised B-Science platform was evaluated through a series of product trials consisting of one-to-one, small-group, and field-test evaluations. These trials were conducted to examine the practicality, usability, and student acceptance of the developed STEM-PjBL web-based learning media.

The one-to-one trial involved three students representing different levels of academic ability. The results showed that B-Science received highly positive responses across all evaluated aspects, including ease of use and navigation (94.40%), attractiveness and design (94.00%), and support for STEM-PjBL and science literacy learning (92.87%). The overall average score reached 93.60%, indicating that the platform was highly feasible and well accepted by students.

Table 6. One-to-One Trial Results

Aspect	Percentage (%)
Ease of Use and Navigation	94.40
Attractiveness and Design	94.00
STEM-PjBL and Science Literacy Support	92.87
Average	93.60

The revised product was subsequently tested in a small-group trial involving ten students. The findings revealed consistently positive responses, with percentages ranging from 90.00% to 96.70%. The highest score was obtained for STEM-PjBL and science literacy support (96.70%), while ease of use and navigation received the lowest score (90.00%).

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Overall, the average score reached 92.72%, indicating that the developed media remained highly feasible for broader implementation.

Table 7. Small-Group Trial Results

Aspect	Percentage (%)
Ease of Use and Navigation	90.00
Attractiveness and Design	91.40
STEM-PjBL and Science Literacy Support	96.70
Average	92.72

The final evaluation was conducted through a field test involving twenty students. Similar to the previous stages, students provided highly positive responses to the developed media. Ease of use and navigation achieved the highest score (95.24%), followed by attractiveness and design (92.06%) and STEM-PjBL and science literacy support (90.48%). The overall average score of 92.06% confirms the practicality and usability of B-Science in actual classroom settings.

Table 8. Field Test Results

Aspect	Percentage (%)
Ease of Use and Navigation	95.24
Attractiveness and Design	92.06
STEM-PjBL and Science Literacy Support	90.48
Average	92.06

Overall, the findings from the three trial stages demonstrate that B-Science was positively received by students and successfully supported science learning activities. The consistently high scores indicate that the platform is attractive, easy to use, and capable of facilitating STEM-PjBL learning while promoting science literacy development among elementary school students. To provide a clearer comparison of student responses across the three evaluation stages, the results are illustrated in Figure 6.

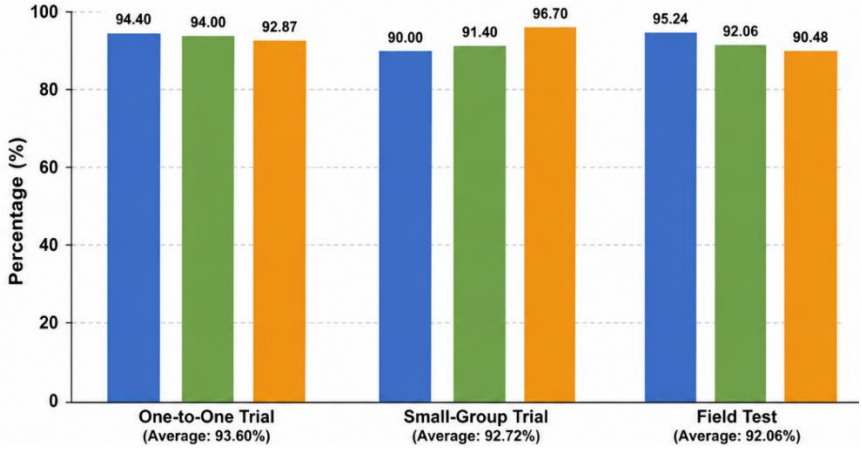

Figure 6. Student Response Results Across Trial Stages

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As shown in Figure 6, all product trial stages achieved average scores above 92%, indicating consistently positive student perceptions of the developed media. The one-to-one trial produced the highest average score (93.60%), followed by the small-group trial (92.72%) and the field test (92.06%). Although slight variations were observed across stages, all results remained within the *very feasible* category. These findings suggest that B-Science possesses a high level of practicality and usability, making it suitable for implementation in elementary science learning environments.

Effectiveness of B-Science in Improving Science Literacy

To obtain an initial overview of students' science literacy performance, descriptive statistics were calculated for both the pretest and posttest scores. The results are presented in Table 9.

Table 9. Descriptive Statistics of Science Literacy Scores

Test	Mean Score
Pretest	47.00
Posttest	87.00

As shown in Table 9, the mean score increased from 47.00 in the pretest to 87.00 in the posttest. This substantial improvement suggests that students achieved better science literacy performance after participating in learning activities using B-Science. To provide a clearer comparison between students' pretest and posttest performance, the mean scores are illustrated in Figure 7.

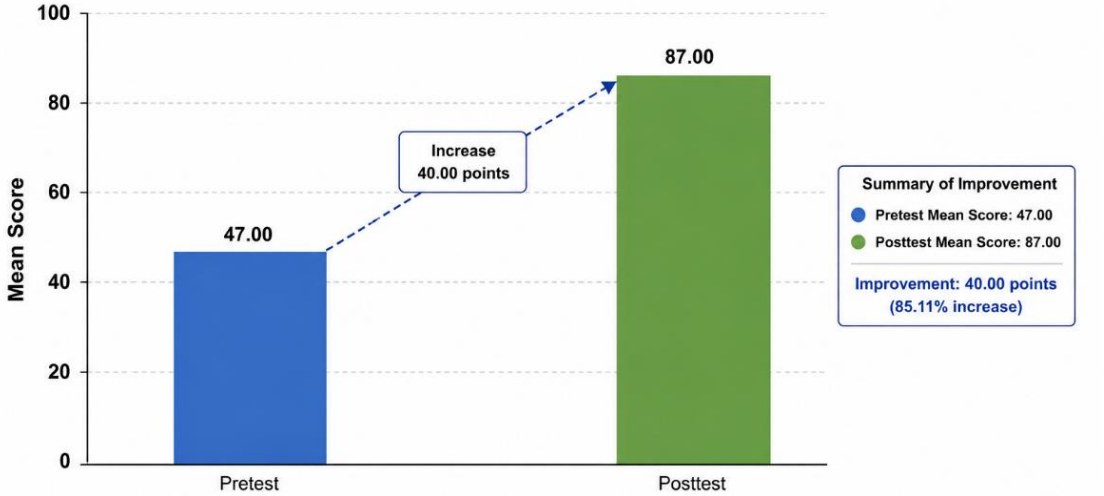

Figure 7. Comparison of Pretest and Posttest Scores

Figure 7 demonstrates a notable increase in students' science literacy scores following the implementation of B-Science. The difference between the pretest and posttest means indicates a positive learning impact of the developed STEM-PjBL web-based learning media.

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Normality Test

Prior to conducting hypothesis testing, a normality test was performed using the Shapiro–Wilk procedure to determine whether the data met the assumptions for parametric analysis. The results are presented in Table 10.

Table 10. Normality Test Results

Data	N	Kolmogorov-Smirnov	Statistic	Sig. Level	Remarks
Pre-Test	31	0,20	0,10	0,05	Normal
Post Test	31	0,09	0,13	0,05	Normal

As presented in Table 10, the significance values for both the pretest (0.20) and posttest (0.13) exceeded 0.05. Therefore, the data were normally distributed and suitable for further analysis using a paired sample t-test.

Paired Sample t-Test

A paired sample t-test was conducted to determine whether there was a statistically significant difference between students' pretest and posttest scores. The results are shown in Table 11.

Table 11. Paired Sample t-Test Results

Data	Sig (2-tailed)	Sig. Level	Remarks
Pretest and Posttest	0,00	0,05	There is a difference

The results in Table 11 indicate a significance value of 0.000, which is lower than the significance level of 0.05. This finding confirms that there was a statistically significant difference between students' science literacy scores before and after the implementation of B-Science.

N-Gain Analysis

To determine the magnitude of students' learning improvement, an N-gain analysis was conducted. The results are presented in Table 12.

Table 12. N-Gain Results

Mean N-Gain	Category
0.76	High

As shown in Table 12, the average N-gain score was 0.76, which falls within the high category. This result indicates that B-Science effectively improved students' science literacy skills.

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Effect Size Analysis

In addition to statistical significance testing, effect size analysis was performed to examine the practical impact of the intervention. The results are presented in Table 13.

Table 13. Effect Size Results

Cohen's d	Interpretation
2.14	Large Effect

The Cohen's d value of 2.14 indicates a large effect size. This finding demonstrates that the implementation of B-Science had a substantial practical impact on students' science literacy achievement. To illustrate the distribution of students' learning gains, the N-gain results are presented graphically in Figure 8.

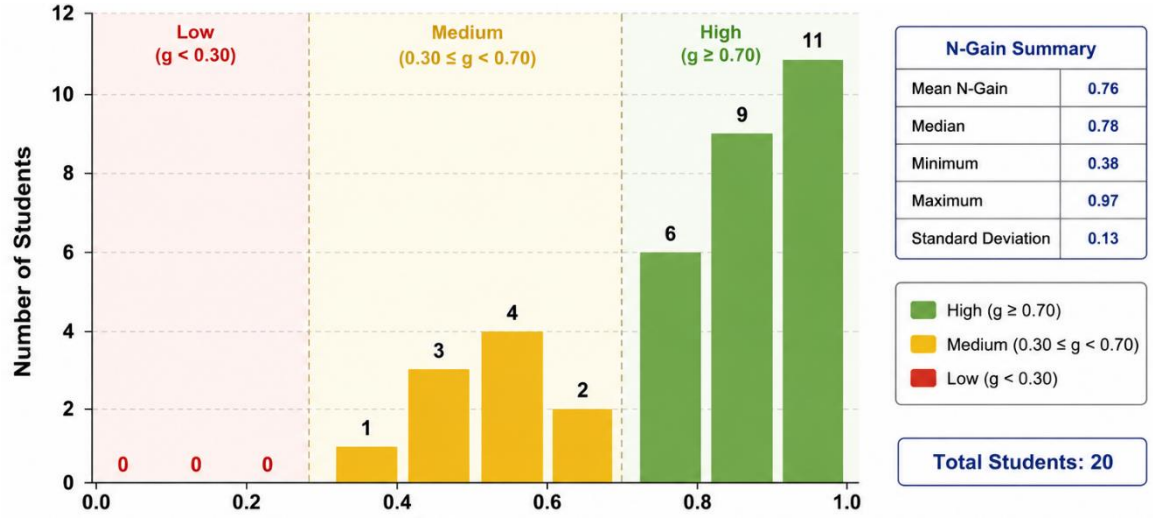

Figure 8. Distribution of Students' N-Gain Scores

Figure 8 shows that most students achieved gains within the high category, indicating that the improvement in science literacy was consistently observed across the participant group. This result further supports the effectiveness of B-Science as a STEM-PjBL web-based learning medium for elementary science education.

D. Discussion

The findings indicate that B-Science possesses a high level of feasibility as a STEM-PjBL web-based learning medium for elementary science education. This conclusion is supported by the overall expert validation score of 90.75%, which falls within the very feasible category. The high validation scores across material, language, and media aspects suggest that the developed platform successfully integrates scientifically accurate content, age-appropriate language, and user-friendly technological features. The inclusion of teaching modules, learning videos, project activities, and science literacy-oriented

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assessments demonstrates that the platform was designed not merely as a content delivery tool but as a comprehensive learning environment that supports active student engagement. These findings indicate that B-Science meets the pedagogical and technical requirements necessary for implementation in elementary school science learning. Such results are consistent with the view that effective educational technology should combine instructional quality, usability, and learner-centered design to support meaningful learning experiences (Hakiki, 2021).

The high feasibility of B-Science can be explained through multimedia learning theory, which argues that students learn more effectively when information is presented through the integration of verbal and visual representations. In the present study, abstract concepts such as the human digestive system and the water cycle were transformed into interactive visualizations, videos, and project-based activities that helped students construct meaningful understanding. This finding is particularly important because elementary school students often experience difficulties in understanding abstract scientific phenomena when instruction relies solely on textbooks and verbal explanations. Therefore, the combination of interactive multimedia and project-based learning activities creates a more supportive learning environment for science literacy development. This argument is supported by Ayu et al (2021), who emphasized that web-based learning environments facilitate flexible and engaging learning experiences, enabling students to access learning resources independently while improving conceptual understanding.

These findings are consistent with previous studies emphasizing the importance of digital learning environments in science education. Shana (2024) reported that web-based learning platforms positively influence students' learning achievement and engagement, while Sidabutar & Sembiring (2023) found that interactive web-based multimedia contributes significantly to science literacy development. Similarly, Rahmadani et al (2024) demonstrated that STEM-PjBL enhances learning motivation, creativity, and conceptual understanding among elementary school students. The present study extends these findings by demonstrating that STEM and Project-Based Learning can be integrated within a single web-based platform that supports the entire learning process, from observation and inquiry to project presentation and evaluation. Unlike previous studies that tended to focus on either STEM implementation or digital learning separately, B-Science integrates both dimensions within a unified learning ecosystem specifically designed to strengthen science literacy.

An important aspect of the present study is the integration of STEM and Project-Based Learning within one digital learning ecosystem. Previous studies have frequently implemented STEM activities and project-based learning separately, while web-based platforms were often limited to the distribution of instructional materials. In contrast, B-Science facilitates the complete STEM-PjBL process through a structured digital environment. Students are guided to observe phenomena, formulate questions, collect information, design projects, develop solutions, and communicate findings. Such integration is particularly relevant because science literacy requires students not only to acquire knowledge but also to apply scientific thinking and problem-solving skills in

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authentic situations. As emphasized by Muzayanati et al (2022), science literacy develops most effectively when learners are actively involved in meaningful scientific practices rather than passive information reception. This finding also aligns with Kotsis (2024), who highlighted the importance of inquiry-oriented science learning experiences in developing students' scientific reasoning and literacy competencies.

The effectiveness analysis further demonstrated that B-Science significantly improved students' science literacy. The mean score increased from 47.00 in the pretest to 87.00 in the posttest, while the paired sample t-test revealed a significance value of 0.000. Moreover, the N-gain score of 0.76 was categorized as high, and the Cohen's d value of 2.14 indicated a large effect size. These results suggest that the observed improvement was not only statistically significant but also educationally meaningful. The findings provide strong evidence that integrating STEM-PjBL within a web-based learning environment can effectively support elementary students in developing science literacy competencies. Considering that science literacy remains a major challenge in Indonesian education, as reflected in international assessments such as PISA (Setyorini et al., 2022), the present findings offer promising evidence regarding the role of technology-enhanced learning in addressing this issue.

Several factors may explain the substantial improvement in students' science literacy. First, the use of interactive visualizations and instructional videos enabled students to develop more accurate mental models of scientific phenomena. Visual learning resources reduce cognitive barriers associated with abstract concepts and facilitate deeper conceptual understanding. Second, the project-based learning activities encouraged students to actively engage in scientific inquiry through observation, investigation, data interpretation, and communication. These activities align closely with the fundamental dimensions of science literacy, including scientific knowledge, inquiry skills, critical thinking, and the ability to apply science in everyday contexts. Consequently, students were not merely learning science content but were also practicing how science is used to understand and solve real-world problems. Such findings support Roy et al (2025), who argued that science literacy develops more effectively when students are actively involved in inquiry-based and evidence-oriented learning experiences from the early years of schooling.

The present findings support previous studies that have reported positive effects of STEM-PjBL on science literacy development. Muskania (2024) found that digital STEM-PjBL teaching materials improve scientific literacy by providing contextual and meaningful learning experiences. Likewise, Nurbayani & Hindriana (2023) reported that STEM-integrated Project-Based Learning enhances students' abilities to organize information, solve problems, and formulate scientific conclusions. Similar findings were reported by Pagala et al (2024), who demonstrated that STEM-PjBL fosters scientific literacy through collaborative and inquiry-based learning processes. The findings are also consistent with Listiyana et al. (2023), who concluded that STEM-oriented learning strategies significantly improve science literacy among elementary school students. However, unlike many previous studies that focused on either STEM activities or web-based learning separately,

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the current study demonstrates the effectiveness of integrating both approaches within a single platform. This finding highlights the importance of combining technological accessibility, interdisciplinary STEM learning, and structured project-based activities to maximize science literacy outcomes.

Overall, the findings suggest that B-Science represents an effective innovation for elementary science education. The platform not only meets the criteria of a valid and practical learning medium but also substantially improves students' science literacy. The integration of STEM principles, project-based learning activities, and web technology provides a learning experience that is interactive, contextual, and accessible. Consequently, this study contributes to the growing body of evidence supporting technology-enhanced STEM education and offers a practical model for strengthening science literacy among elementary school students in the digital era. More importantly, the study contributes a novel approach by demonstrating how STEM-PjBL can be systematically embedded within a single web-based ecosystem, enabling students to engage in inquiry, collaboration, and scientific problem-solving through a flexible and technology-supported learning environment.

E. Implication

The findings of this study have important implications for elementary science education in the digital era. The successful implementation of B-Science demonstrates that integrating STEM principles, Project-Based Learning, and web-based technology within a single learning ecosystem can effectively support the development of science literacy among elementary school students. This suggests that digital learning platforms should be designed not only as repositories of learning materials but also as environments that actively engage students in inquiry, problem-solving, collaboration, and scientific communication. For teachers, B-Science provides a practical model for implementing STEM-PjBL in a structured and accessible manner, while for schools, it offers evidence that existing technological resources, such as smartphones and internet access, can be utilized to enhance learning quality without requiring sophisticated infrastructure. Furthermore, the findings contribute to ongoing efforts to strengthen science literacy and twenty-first-century skills, supporting curriculum initiatives that emphasize active, technology-enhanced, and student-centered learning. Ultimately, this study highlights the potential of integrated web-based STEM-PjBL learning environments as a sustainable strategy for improving science education and preparing students to meet the demands of an increasingly complex and technology-driven world.

F. Limitation and Suggestion for Further Research

This study has several limitations that should be considered when interpreting the findings. First, the research employed a one-group pretest–posttest design without a control group, which limits the ability to fully attribute the observed improvements solely to the implementation of B-Science. Second, the study involved only 31 fifth-grade students from

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a single elementary school in East Jakarta, thereby restricting the generalizability of the findings to broader educational contexts. In addition, the intervention was conducted on two science topics, namely the human digestive system and the water cycle, so the effectiveness of the platform for other science contents remains to be further explored.

Despite these limitations, the findings provide promising evidence regarding the potential of STEM-PjBL web-based learning media for improving science literacy. Therefore, future studies are recommended to employ quasi-experimental or experimental designs involving control groups to obtain stronger evidence of causal effects. Researchers are also encouraged to conduct large-scale implementations across schools with different geographical, social, and educational characteristics to enhance the generalizability of the findings. Furthermore, future research may investigate the long-term impact of B-Science on science literacy, critical thinking, and digital literacy, as well as adapt the platform for other science topics and educational levels to further expand its educational applicability and effectiveness.

G. Conclusion

This study successfully developed B-Science, a STEM-PjBL web-based science learning medium for fifth-grade elementary school students using the Hannafin and Peck development model. The findings demonstrated that the developed media achieved a very high level of feasibility, as indicated by the overall expert validation score of 90.75%, and received highly positive responses from students across all product trial stages. Furthermore, the effectiveness analysis revealed a significant improvement in students' science literacy, as evidenced by the increase in mean scores from 47.00 in the pretest to 87.00 in the posttest, a significant paired sample *t*-test result ($p < 0.05$), a high N-gain score of 0.76, and a large effect size (Cohen's $d = 2.14$). These findings indicate that the integration of STEM principles, Project-Based Learning, and web-based technology within a single learning ecosystem can effectively support science literacy development by providing interactive, contextual, and inquiry-oriented learning experiences. Therefore, B-Science can be considered a valid, practical, and effective learning medium that contributes to strengthening elementary students' science literacy and offers an innovative model for technology-enhanced science education in the twenty-first century.

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