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Interactive Science Learning Innovation Management through the Design of Science Literacy-Based E-LKPD to Improve Conceptual Understanding

Fitri Siti Sundari[1*], Resyi A. Gani[2], Mursidah Rahmah[3], Nur Maulidia[4], Keumala Septiyana Rizky[5]
[1,2,3]Teacher Professional Education Department, Universitas Pakuan, West Java, Indonesia
[4,5]Primary Teacher Education Department, Universitas Pakuan, West Java, Indonesia
Email: fitri.siti.sundari@unpak.ac.id[1], resyi@unpak.ac.id[2], mursidah@unpak.ac.id[3], nur_maulida@gmail.com[4], keumala_septiriz@gmail.com[5]

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Abstract:

This study aims to develop a science literacy-based Electronic Student Worksheet (E-LKPD) to improve elementary students' conceptual understanding of science, assess its feasibility, and evaluate its effectiveness. Using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation), the E-LKPD was developed with Canva and a live worksheet, focusing on the topic of force and motion. Expert validation showed high feasibility scores: 93% from the media expert, 95% from the language expert, and 94% from the material expert. A limited trial involving 30 fourth-grade students yielded positive responses: 92.42% from the students and 98% from the teachers. Pretest and posttest results showed an average N-Gain of 0.12 to 0.16, which falls within the low to moderate category. However, the Paired Sample T-Test produced p-values < 0.05 for all indicators, indicating statistically significant differences between pretest and posttest scores. This suggests that although the quantitative gain was modest, students' conceptual understanding of science improved meaningfully. The findings indicate that the E-LKPD is highly feasible and effective for supporting science instruction. This research supports deeper conceptual learning, development of 21st-century skills, learning innovation, the Merdeka Curriculum, and teacher competency in integrating digital science-literacy tools.

Keywords: *E-LKPD, Science Literacy, Independent Curriculum, Teacher Competence*

Abstrak:

Penelitian ini bertujuan untuk mengembangkan Lembar Kerja Peserta Didik Elektronik (E-LKPD) berbasis literasi sains untuk meningkatkan pemahaman konsep sains siswa sekolah dasar, menilai kelayakannya, serta mengevaluasi keefektifannya. Dengan menggunakan model ADDIE (Analysis, Design, Development, Implementation, Evaluation), E-LKPD dikembangkan melalui Canva dan Liveworksheet dengan topik gaya dan gerak. Hasil validasi ahli menunjukkan skor kelayakan yang tinggi: 93% dari ahli media, 95% dari ahli bahasa, dan 94% dari ahli materi. Uji coba terbatas pada 30 siswa kelas IV menghasilkan respons positif: 92,42% dari siswa dan 98% dari guru. Hasil pretest dan posttest menunjukkan rata-rata N-Gain sebesar 0,12 hingga 0,16 yang termasuk kategori rendah hingga sedang. Namun, uji Paired Sample T-Test menghasilkan nilai p < 0,05 untuk semua indikator, yang menunjukkan perbedaan signifikan secara statistik antara skor pretest dan posttest. Hal ini mengindikasikan bahwa meskipun peningkatan kuantitatif tergolong rendah, pemahaman konsep sains siswa tetap mengalami peningkatan yang bermakna. Temuan ini menunjukkan bahwa E-LKPD sangat layak dan efektif untuk mendukung pembelajaran sains. Penelitian ini

berkontribusi pada penguatan pembelajaran konseptual yang lebih mendalam, pengembangan keterampilan abad ke-21, inovasi pembelajaran, implementasi Kurikulum Merdeka, serta peningkatan kompetensi guru dalam mengintegrasikan perangkat digital berbasis literasi sains.
Kata Kunci: *E-LKPD, Literasi Sains, Kurikulum Merdeka, Kompetensi Guru*

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INTRODUCTION

Science education at the elementary school level is integral to building students' foundational scientific knowledge and skills. Education lays the groundwork for developing critical thinking, problem-solving abilities, and a deeper understanding of the natural world (Fitriyah et al., 2024; Pasquinelli et al., 2021). However, despite the growing importance of science in shaping future generations, several studies show that Indonesian elementary students face significant challenges in grasping scientific concepts (Irwan et al., 2024). These challenges are reflected in international assessments such as the Programme for International Student Assessment (PISA), where Indonesian students perform below average in science (Blyznyuk & Kachak, 2024; Verawati & Sarjan, 2023). One of the root causes lies in management-related issues within the education system: traditional teaching practices that emphasize rote memorization, limited innovation in instructional planning, and insufficient managerial support for curriculum development and teacher training (Shanta & Wells, 2022; Shutaleva, 2023). Furthermore, the absence of engaging, interactive, and contextually relevant learning materials further complicates classroom management, thereby reducing students' motivation and participation. Thus, innovation in science education must also be viewed as an effort to improve the management of learning resources and strategies in schools.

Science literacy is a vital component of education, encompassing the ability to explain scientific phenomena, design investigations, and interpret data (Almulla, 2023; Moustaghfir & Brigui, 2024). However, Indonesian students' performance in science remains below the international average, especially in applying knowledge to real-life situations (Valladares, 2021). This gap highlights the need for effective managerial decisions in designing and implementing practical, interactive learning tools that connect science with everyday experiences. For instance, integrating digital learning resources such as Electronic Student Worksheets (E-LKPD) requires not only technological innovation but also managerial strategies to ensure accessibility, teacher readiness, and systematic evaluation of learning outcomes (Birren & Stout, 2022; Meutia et al., 2021; Sinaga et al., 2022).

The low levels of science literacy among Indonesian elementary students are not only caused by inadequate learning materials but also reflect broader management challenges in the education system. Many schools, particularly in rural areas, struggle with limited access to quality resources and infrastructure, which demonstrates weaknesses in educational planning and resource allocation (Sutiani et al., 2021). Furthermore, insufficient teacher training in integrating technology is a managerial issue that directly affects the effectiveness of instructional delivery (Jubba et al., 2021). The lack of strategic management in technology integration—such as providing infrastructure, continuous professional development, and monitoring—hinders the adoption of innovative tools like E-LKPDs (Agus et al., 2021; Lenchuk & Mosiiuk, 2023). Therefore, addressing science literacy requires not only pedagogical innovation but also improvements in educational management to ensure equity, efficiency, and sustainability in science teaching.

Previous studies have confirmed the potential of digital and interactive resources to enhance students' conceptual understanding. For example, scientific literacy-based E-LKPDs have been shown to support personalized learning and enhance conceptual mastery in topics such as growth and development (Rochim et al., 2022; Mulyasari et al., 2022; Silfiyani et al., 2024). Multimedia integration has also been proven to improve comprehension and retention (Putra et al., 2023), while interactivity boosts students' engagement (Febriningtyas & Dwiningsih, 2024). However, few studies have investigated how these digital tools can be systematically managed and institutionalized within schools, especially in the Indonesian context. This indicates a management gap: the absence of structured policies and strategies to align curriculum demands, digital innovation, and teacher capacity building.

Therefore, this study aims to fill that gap by developing and implementing a science literacy-based Electronic Student Worksheet (E-LKPD) for elementary students in Indonesia, specifically on the topic of "Forces and Motion" in Grade 4 at Kaumsari State Elementary School, Bogor City. Beyond its pedagogical contribution, the study highlights the managerial dimension, including aligning digital learning resources with curriculum standards, ensuring teacher readiness through capacity building, and effectively managing resources to provide equitable access for students. The novelty of this study lies not only in integrating scientific literacy principles into E-LKPDs but also in highlighting their role in improving classroom and institutional management of science education. By doing so, this research contributes to both the field of educational technology and the management of science education in elementary schools.

RESEARCH METHOD

This study employed the Research and Development (R&D) method, utilising the ADDIE model, which comprises five stages: Analysis, Design, Development, Implementation, and Evaluation. Instrument validity was ensured through expert judgment, with media, language, and material experts conducting content validation of the E-LKPD and student questionnaires. The reliability of the questionnaire was assessed statistically using Cronbach’s Alpha. The pretest and posttest instruments were analysed for validity through item analysis and reliability using Cronbach’s Alpha to confirm internal consistency (Spatioti et al., 2022). In the Analysis stage, the researcher identified student needs and aligned the content with the curriculum to select appropriate science material, specifically the topic “Forces and Motion.” The Design phase involved creating a learning plan that suited students’ characteristics and integrated principles of scientific literacy.

During the Development phase, the E-LKPD was produced using Canva and live-worksheet platforms, incorporating interactive features such as multimedia elements and digital quizzes to enhance engagement and conceptual understanding. Data analysis was conducted using SPSS version 20, with N-Gain values calculated (Matović & Ovesni, 2023). The interpretation of N-Gain followed the standard low ($g < 0.3$), medium ($0.3 \le g < 0.7$), and high ($g \ge 0.7$) categories, providing a clearer picture of students' conceptual improvement.

The Implementation stage involved a limited trial conducted with 30 fifth-grade students at SDN Kaumsari over two weeks of science lessons. Participants were selected purposively to represent a typical classroom setting in terms of academic diversity and access to digital tools. During this stage, data were collected using multiple instruments, including observation sheets to measure practicality, student and teacher questionnaires to capture perceptions and engagement, and pretest–posttest assessments to evaluate conceptual understanding (Åkerblad et al., 2021). In the Evaluation stage, the E-LKPD was examined for validity by expert reviewers, its practicality was assessed through classroom observations and questionnaire results, and its effectiveness was determined from students' learning outcomes and statistical analysis of performance improvements. A visual representation of the ADDIE development cycle is presented in Figure 1.

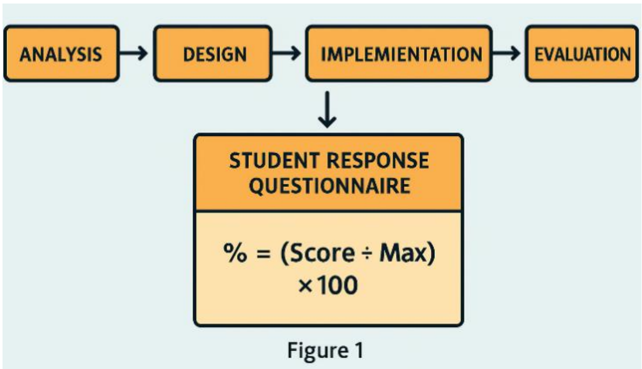

Figure 1. R&D Cycle Using the ADDIE Model

The development process in this study follows the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), which is a systematic approach to producing valid and effective learning products (Redhuan et al., 2021). This model is suitable for developing science literacy-based digital learning media due to its structured and iterative nature.

Table 1. ADDIE Development Stages in the Study

Addie Phase	Activities	Outputs	Indicators of Achievement
Analysis	Classroom observation, teacher and student interviews	Needs analysis and learning problem data	Needs analysis report, field documentation
Design	E-LKPD planning (content, format, interactivity)	Draft of science literacy-based E-LKPD design	Initial design documents, storyboard, table of contents

Development	Digital media development, expert validation (media, language, content)	Validated version of E-LKPD	Validation score ≥ 80% from three experts
Implementation	Limited trial in Grade IV, data collection (pretest, questionnaires)	Effectiveness data, teacher and student feedback	30 students and teacher respondents
Evaluation	Data analysis (t-test, gain score, normality), product revision	Effectiveness report and final E-LKPD revision	Pre-post test results, revised product documentation

The validation of the E-LKPD by media experts aimed to gather feedback regarding design aspects, ensuring that the final product met usability and pedagogical standards. Expert validation played a crucial role in refining the quality and functionality of the media. The research instruments included a pretest and posttest consisting of 20 multiple-choice questions that measured students' conceptual understanding of "Forces and Motion," covering indicators such as identifying types of forces, explaining their effects on objects, and applying concepts in real-life contexts. In addition, a student response questionnaire was administered using a 4-point Likert scale (strongly agree to strongly disagree), with indicators including attractiveness of the media, ease of use, clarity of instructions, and contribution to learning motivation. Examples of questionnaire items are: "The E-LKPD design is visually interesting" and "The E-LKPD helps me better understand the topic of force and motion." The stages of the ADDIE model used in this research are illustrated in Figure 1 and further detailed in Table 1.

RESULT AND DISCUSSION

Result

Analysis

Classroom observations and interviews with Grade V students and their teacher revealed that scientific literacy was not fully integrated into science lessons. Teachers relied mainly on conventional worksheets (LKPD) that were text-heavy, unattractive, and lacked interactive elements. Results from an initial diagnostic assessment revealed that the average student score in daily science tests was 58 out of 100, which is below the school's minimum mastery criterion (KKM). Furthermore, interview data indicated that only about 20% of students reported having prior experience conducting simple science experiments, suggesting limited opportunities for active engagement in scientific inquiry. These findings indicate shortcomings in classroom management practices, where instructional time and learning resources were not optimally allocated to foster inquiry-based learning.

Furthermore, 60% of the interviewed students noted that they rarely used LKPD in their science learning. When LKPDs were used, they were typically the ones found in textbooks. Although students expressed that such worksheets slightly motivated them, they overwhelmingly hoped for a more engaging digital version. From a management perspective, this highlights weaknesses in resource management, as schools have not yet provided innovative and varied learning materials that align with students' needs. The students' preference for digital

LKPDs also underscores the importance of technology management within schools, where administrators must ensure the procurement, accessibility, and sustainability of digital tools to improve learning outcomes.

Interviews conducted with four Grade IV teachers revealed that while elements of science process skills had been integrated into teaching, such as practical activities and the use of worksheets (LKPD), the full implementation of scientific literacy was not yet achieved. The interview data revealed that most teachers emphasised observation as the primary literacy component, with limited attention to other dimensions, such as explanation, evidence-based reasoning, and communication. To present the results more systematically, the interview responses were categorised into key aspects of scientific literacy (observation, explanation, reasoning, communication), and their frequencies were tabulated. An example of the summary is presented in Table 2, which shows that 75% of teachers emphasised observation, while less than 25% mentioned other aspects of scientific literacy.

Table 2. Summary of Teacher Interview Results on the Implementation of Scientific Literacy

Aspect of Scientific Literacy	Number of Teachers Mentioned (n=4)	Percentage (%)
Observation	3	75%
Explanation	1	25%
Evidence-based reasoning	1	25%
Communication	0	0

The students' feedback, indicating a lack of prior experience with hands-on scientific inquiry and experiments, highlights the need for more opportunities for active engagement, which is crucial for developing scientific literacy. From a management perspective, this gap demonstrates weaknesses in instructional management, where teaching strategies remain focused on observation while neglecting higher-order skills such as explanation, reasoning, and communication. The infrequent and ineffective use of LKPDs further illustrates the absence of systematic curriculum and material management, limiting opportunities for structured inquiry-based learning.

Moreover, the students' desire for digital LKPDs underscores the managerial need for schools to adopt technology-based innovations as part of their strategic planning. Effective educational management should ensure teacher training in digital pedagogy, allocate budgets for technological resources, and create policies that integrate digital tools into daily instruction. Without such management interventions, even well-designed digital resources may not achieve their intended impact.

In summary, the findings show that challenges in scientific literacy are not solely pedagogical but also managerial, involving classroom management, resource allocation, curriculum implementation, and teacher capacity building. Addressing these management dimensions is essential for creating a sustainable system that supports both the integration of scientific literacy and the effective use of innovative digital learning tools such as E-LKPDs.

Design Phase

The design components of the E-LKPD consisted of a cover page, foreword, table of contents, learning objectives, and six central units—E-LKPD 1 (Effects of Force), E-LKPD 2 (Muscular Force), E-LKPD 3 (Frictional Force), E-LKPD 4 (Magnetic Force), E-LKPD 5 (Elastic Force), and E-LKPD 6 (Gravitational Force). In the Design phase, the researcher created a science literacy-based E-LKPD in PDF format, which was then uploaded to the Liveworksheets platform. The final E-LKPD was made accessible to students in HTML format. Additional sections included a bibliography and an author profile to support academic integrity and contextual relevance. Rather than presenting the development steps procedurally, the pedagogical features of the E-LKPD and their alignment with scientific literacy indicators are summarised in Table 3.

Table 3. Pedagogical Features

Feature in E-LKPD	Pedagogical Function	Linked Scientific Literacy Indicator
Cover, foreword, and usage instructions	Provides clarity, structure, and motivation for learning	Communicating scientific information clearly
Learning objectives	Guides students toward targeted competencies	Understanding the purpose and relevance of scientific knowledge
Sub-material sections with images and examples	Supports comprehension through visual representation and contextualized explanations	Explaining phenomena scientifically
Practice questions with interactive elements	Encourages active engagement and application of concepts	Applying scientific knowledge and reasoning based on evidence
Virtual/interactive exercises (quizzes, matching)	Promotes exploration, experimentation, and immediate feedback	Using scientific procedures and interpreting data
Bibliography and references	Trains students to acknowledge sources and foster academic honesty	Recognizing the role of science in society and responsible practices
Author's profile	Builds trust and models professionalism in communication	Reflecting on the nature and practice of science
Cross-platform accessibility (laptop & smartphone)	Expands opportunities for digital literacy and flexible learning contexts	Engaging with science-related tools in daily life

Development

The developed E-LKPD was subjected to a validation process to determine its feasibility for use. The validation was carried out by three experts—namely, media, language, and content experts—by assigning validity scores to the E-LKPD through a validation questionnaire. The validation scores obtained were then converted into percentages to determine the overall feasibility level of the E-LKPD. In addition, the experts provided suggestions and feedback to enhance the quality of the E-LKPD.

Media Expert

Based on the media validation questionnaire, which consisted of 15 statements rated on a scale of 1 to 5, the maximum possible score was 75 (15 items

× 5 points). The validity percentage was calculated by comparing the obtained score with the maximum score. The results were then categorised according to the following criteria: 0–20% = very invalid, 21–40% = invalid, 41–60% = moderately valid, 61–80% = valid/feasible, and 81–100% = highly valid/highly feasible. To ensure the consistency of expert assessments, the results were examined using inter-rater agreement, showing a high level of consistency across validators.

Table 4. Final Results of Media Expert Validation

Validation	Validity Percentage	Feasibility Category
First	80%	Valid/Feasible
Second	93%	Highly Valid/Feasible

The results indicate that the E-LKPD design improved after revisions based on expert input, moving from the "valid/feasible" category (80%) in the first validation to the "highly valid/highly feasible" category (93%) in the second validation. This improvement demonstrates that feedback from media experts effectively enhanced the visual design, usability, and pedagogical alignment of the E-LKPD. The high consistency among validators further strengthens the conclusion that the E-LKPD meets the standards of feasibility for classroom implementation.

Language Expert

The validation of the E-LKPD by the language expert aimed to obtain information, critiques, and suggestions regarding the linguistic aspects, ensuring that the product would be improved in terms of clarity, readability, and alignment with students' comprehension levels. The language validation questionnaire consisted of 12 items rated on a scale of 1 to 5, with an ideal maximum score of 60 (12 × 5). The validity percentage was calculated and interpreted using the following criteria: 0–20% = very invalid, 21–40% = invalid, 41–60% = moderately valid, 61–80% = valid/feasible, and 81–100% = highly valid/highly feasible. To assess the consistency of expert judgments, Aiken's V was applied, producing a value above 0.80, which indicates strong inter-rater agreement.

Table 5. Final Results of Language Expert Validation

Validation	Validity Percentage	Feasibility Category
First	82%	Valid/Feasible
Second	93%	Highly Valid/Feasible

The results indicate that revisions based on expert feedback successfully improved the linguistic quality of the E-LKPD, as reflected in the increase from 82% ("valid/feasible") in the first validation to 93% ("highly valid/highly feasible") in the second validation. The relatively low standard deviation (±3.5) suggests that expert ratings were consistent and reliable. However, it is important to note that teacher feedback was obtained from a single participant, which limits the generalizability of the conclusions.

Content Expert

The following presents the validation results from the content expert for the science literacy-based E-LKPD on the topic of force and motion. The content validation questionnaire consisted of 20 items rated on a 1–5 scale, with an ideal maximum score of 100. The validity percentage was calculated and interpreted using the criteria: 0–20% = very invalid, 21–40% = invalid, 41–60% = moderately valid, 61–80% = valid, and 81–100% = highly valid. To ensure consistency, Aiken's V was applied, yielding a value above 0.85, indicating strong inter-rater reliability.

Table 6. Final Results of Content Expert Validation

Validation	Validity Percentage	Feasibility Category
First	88%	Highly Valid/Feasible
Second	94%	Highly Valid/Feasible

The results show that the content aspect of the E-LKPD improved from the first (88%) to the second validation (94%), placing it consistently in the "highly valid/feasible" category. This suggests that the instructional content aligns well with science literacy principles and elementary curriculum standards. However, while expert validation confirms the quality of the content, student learning outcomes showed only low N-Gain values (0.12–0.16), categorised as "low." Despite this, the paired sample t-test revealed statistically significant differences ($p < 0.05$) between pre- and post-test scores, indicating that although the improvement in conceptual understanding was modest, the intervention still had a meaningful impact.

Based on the validation results from all three experts, media, language, and content, it is possible to calculate the Overall Validity Mean Score (RTV), which is then converted to determine the conclusion regarding the validity test of the E-LKPD. The summarised data is presented in the following Figure 2.

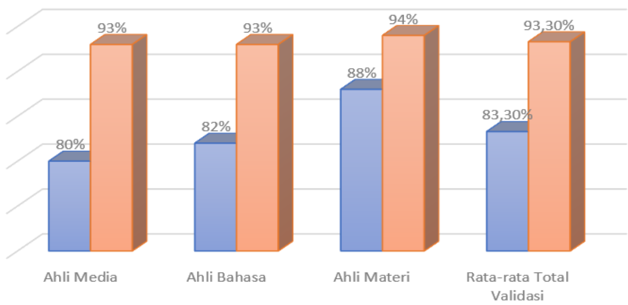

Figure 2. Results of the Feasibility of E-LKPD Based on Science Literacy

The following are the results of the feasibility of the E-LKPD product based on scientific literacy,

Table 7. Feasibility Results of the Science Literacy-Based E-LKPD

Validator	Feasibility Result	
	I	II
Media Expert	Feasible	Highly Feasible
Language Expert	Highly Feasible	Highly Feasible
Content Expert	Highly Feasible	Highly Feasible
Average Total Validity	Highly Feasible	Highly Feasible

According to Table 7 above, the science literacy-based E-LKPD on the topic of force and motion is considered highly feasible for use by students in terms of its media, language, and content aspects. This is supported by the average total validity scores of 83.3% in the first validation and 93.3% in the second validation.

Implementation

The implementation phase was conducted in a fifth-grade elementary school class comprising 30 students, aiming to assess the effectiveness of the E-LKPD in enhancing conceptual understanding of science. Based on the recapitulation of student responses, the use of the science literacy-based E-LKPD received very positive evaluations. The overall average response score was 93.1%, which falls within the qualification range of $80\% < x \leqslant 100\%$, indicating that the product is highly feasible for classroom use. From a management perspective, this finding demonstrates the importance of instructional management, particularly in selecting and integrating innovative digital tools that can optimize student engagement and learning outcomes.

A closer look at the distribution of responses shows that 90% of students strongly agreed that the E-LKPD was more interesting than the conventional worksheet (LKPD), 87% reported that the digital features made it easier to understand abstract concepts such as gravity and magnetism, and 85% agreed that the interactive exercises motivated them to participate more actively in class. These findings highlight not only pedagogical benefits but also managerial implications: effective classroom management strategies are needed to ensure that interactive features are used optimally, while technology management within schools must support stable access to digital devices and resources. In other words, the positive reception of E-LKPD suggests that school leaders need to plan for systematic integration of such tools into daily instructional practices.

Teacher feedback also confirmed the feasibility of the product, with a validity score of 93%. According to the feasibility classification ($80\% < x \leqslant 100\%$), this percentage indicates that the E-LKPD is highly feasible for teaching purposes. The teacher noted that the E-LKPD provided clear instructions, appropriate materials for elementary learners, and strong alignment with curriculum goals. These results underscore the significance of curriculum management, where instructional materials must not only meet pedagogical standards but also align with broader curriculum objectives. Additionally, teachers' positive responses reflect the role of human resource management, which involves equipping teachers with training and support to implement digital tools effectively.

Despite these promising results, teacher feedback was obtained from only one respondent, and the implementation trial was limited to a single school. Therefore, while the findings suggest that the E-LKPD has strong potential, broader testing across multiple schools and involving more teachers is necessary to strengthen the generalizability of the conclusions. This limitation also points to the importance of quality management and evaluation in education, where innovations must undergo systematic trials, monitoring, and continuous improvement before being scaled up for wider use.

Evaluation

The evaluation phase consisted of two key aspects: assessing the quality of the E-LKPD and measuring the improvement in students' understanding of scientific concepts through pretest and posttest assessments. The effectiveness test aimed to determine the extent to which the science literacy-based E-LKPD could enhance conceptual understanding among elementary school students. To achieve this, a comparison was made between pretest scores (before using the E-LKPD) and posttest scores (after using the E-LKPD). The effectiveness of the E-LKPD was measured using the Normalised Gain (N-Gain).

Table 8. N-Gain Calculation Results

Indicator	Pretest (%)	Post-test (%)	Difference (%)	N-Gain	Category
Restating a concept	58.0	72.0	14.0	0.14	Low
Classifying objects based on a specific concept	59.0	70.6	11.6	0.12	Low
Providing examples and non-examples of a concept	63.0	77.2	14.2	0.14	Low
Applying concepts to problem-solving	62.0	77.0	15.0	0.15	Low
Connecting various concepts	64.0	80.0	16.0	0.16	Low

Table 8 presents the results for each indicator. All indicators demonstrated N-Gain values between 0.12 and 0.16, which fall into the low category (N-Gain < 0.3). Although these values indicate that the magnitude of improvement was limited, the consistent positive gains across all indicators suggest that the E-LKPD did contribute to enhancing conceptual understanding. From a management perspective, this reflects the importance of learning process management—particularly how innovation must be integrated systematically into classroom activities. The low gain may also relate to time management in implementation, since the relatively short intervention period limited students' ability to fully explore the features of the E-LKPD. Additionally, as students were engaging with a digital worksheet format for the first time, change management becomes essential, requiring gradual adaptation and teacher facilitation to optimise learning outcomes.

In addition to the N-Gain analysis, a Paired Sample T-Test was conducted to examine whether the differences between pretest and posttest scores were statistically significant.

Table 9. Paired Sample T-Test Results

Indicator	t-statistic	df	p-value
Restating a concept	-6.12	29	0.000
Classifying objects based on a specific concept	-4.68	29	0.001
Providing examples and non-examples of a concept	-6.25	29	0.000
Applying concepts to problem-solving	-6.85	29	0.000
Connecting various concepts	-7.18	29	0.000

All indicators showed p-values < 0.05, confirming that the differences between pretest and posttest scores were statistically significant. This indicates that, although the level of improvement was categorised as low, the E-LKPD still had a significant positive effect on students’ conceptual understanding.

From a management of educational quality perspective, these results highlight that digital innovations like the E-LKPD require not only effective instructional design but also structured management in terms of teacher readiness, infrastructure support, and systematic evaluation. While statistically significant improvements were achieved, the low gain category suggests that schools need to strengthen curriculum management (allocating more time for science inquiry), resource management (ensuring sufficient access to digital tools), and teacher professional development management (enhancing teachers’ digital pedagogy skills).

Based on the combined results of the N-Gain analysis and Paired Sample T-Test, it can be concluded that the science literacy-based E-LKPD produced statistically significant improvements in conceptual understanding despite being in the low-gain category. This finding underscores the potential of the E-LKPD as a pedagogical tool but also highlights managerial implications: more extended implementation periods, broader classroom trials, and systematic planning at the school management level are essential to achieve higher levels of learning effectiveness.

Discussion

The findings of this study underscore a common challenge observed in educational technology implementations: the discrepancy between high validation results and limited learning gains. The positive validation results, where experts rated the E-LKPD as highly feasible and both teachers and students expressed strong approval, are consistent with similar findings in the literature. E-LKPDs were also found to be engaging and aligned with learning objectives (Silfiyani et al., 2024). However, the relatively low N-Gain scores in this study highlight a critical gap between user satisfaction and actual learning outcomes. From a management perspective, this discrepancy points to the need for better alignment between instructional innovation and learning process management, ensuring that tools validated as effective are also systematically integrated into classroom practices to achieve measurable improvements.

The findings from the low N-Gain scores (0.12–0.16) suggest that the duration of the intervention may have been insufficient for students to fully benefit from the E-LKPD. This issue of time management aligns with the research of Birren and Stout (2022), who observed that the effectiveness of digital learning resources often depends on the amount of time students spend engaging with the content. In this context, curriculum management becomes crucial, as schools must allocate sufficient lesson hours and provide structured opportunities for extended engagement with digital resources. Without managerial planning for longer implementation, the potential of such innovations cannot be fully realised.

Additionally, the students' initial unfamiliarity with digital E-LKPDs is a crucial factor that might have hindered learning outcomes. This reflects the importance of change management in educational institutions, where the introduction of new technologies requires gradual adaptation, scaffolding, and student training. As Omirzak et al. (2022) note, students’ first interactions with digital tools can increase cognitive load, diverting attention from learning content. From a management angle, this highlights the necessity of structured orientation sessions and teacher facilitation strategies to reduce barriers during the transition.

Another managerial implication arises from the early stage of integrating scientific literacy into Indonesian elementary classrooms. The successful integration of scientific literacy requires not only alignment with curriculum objectives but also human resource management in the form of continuous teacher professional development. Teacher interviews in this study confirm that most educators emphasised observation over other scientific literacy aspects. This narrow focus indicates the need for capacity-building programs managed at the school or district level to equip teachers with inquiry-based pedagogical skills (Ataman et al., 2024; Adams et al., 2023). Without systematic investment in teacher competence, the sustainability of innovations like the E-LKPD will remain limited.

The implications of these findings are twofold. Theoretically, embedding scientific literacy into digital worksheets is a viable framework for supporting curriculum reforms in elementary science. Practically, the results underscore the importance of school management strategies that provide extended and repeated implementation cycles, structured teacher training, and sufficient resource allocation. This way, students can move beyond initial engagement toward a deeper conceptual understanding. Moreover, the findings emphasise that educational quality management must address not only the design of innovative tools but also the processes of implementation, monitoring, and continuous evaluation.

This study has limitations. The sample size was small (n = 30), the intervention was conducted in a single school, and the duration of exposure was relatively short. Furthermore, teacher responses were limited to a single individual, restricting the generalizability of the findings. Future research should therefore involve larger and more diverse samples, extend the intervention period, and include multiple teachers and school contexts. From a management standpoint, this would allow for broader evaluation, better-informed decision-making, and more sustainable scaling of digital learning innovations across schools.

CONCLUSION

This study demonstrates that the science literacy-based E-LKPD, developed using the ADDIE model and implemented with Canva and Live-worksheet, is a valid and feasible innovative digital learning resource for elementary science. Validation results from experts and user feedback from students and teachers consistently rated the product as "highly feasible," aligning well with pedagogical, media, and linguistic standards. However, despite improving student scores, the low N-Gain values (0.12–0.16) suggest that conceptual gains remain limited, indicating a need for better time management, structured lesson planning, and gradual familiarization for both teachers and students.

The main contribution of this study lies in integrating the framework of scientific literacy into the design of a digital E-LKPD at the elementary school level. Unlike previous research that mainly focused on isolated content areas, this study shows how interactive digital worksheets can be systematically developed and validated as part of a broader effort to strengthen scientific literacy in line with curriculum reforms. The effectiveness of the E-LKPD will depend on how well schools manage its integration, ensuring that teacher training, curriculum alignment, and ongoing evaluation are addressed to maximize its impact on students' scientific literacy.

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