



**BRIDGING PEDAGOGY AND TECHNOLOGY: DEVELOPMENT AND EVALUATION OF A PBL-BASED LKPD ELEKTRONIK TO ENHANCE PROBLEM-SOLVING ABILITY AND SCIENCE PROCESS SKILLS**

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**ABSTRAK**

Rendahnya keterampilan berpikir tingkat tinggi peserta didik dalam pembelajaran sains menunjukkan bahwa integrasi teknologi dan pedagogi belum dilaksanakan secara optimal. Penelitian ini bertujuan untuk mengembangkan dan mengevaluasi lembar kerja peserta didik elektronik (e-LKPD) berbasis Problem-Based Learning (PBL) ditinjau dari aspek validitas, kepraktisan, dan efektivitas dalam meningkatkan kemampuan pemecahan masalah dan keterampilan proses sains peserta didik. Penelitian menggunakan pendekatan Research and Development (R&D) yang dipadukan dengan desain quasi experiment melalui kelompok eksperimen dan kelompok kontrol. Tahapan penelitian meliputi pengembangan produk, validasi ahli, uji coba terbatas, serta implementasi pada proses pembelajaran. Hasil penelitian menunjukkan bahwa e-LKPD berbasis PBL yang dikembangkan berada pada kategori sangat valid dan sangat praktis berdasarkan hasil validasi ahli serta respons positif pengguna. Dari aspek efektivitas, kelompok eksperimen menunjukkan peningkatan yang lebih tinggi dibandingkan kelompok kontrol dengan nilai N-Gain kemampuan pemecahan masalah sebesar 0,60 dan keterampilan proses sains sebesar 0,50 yang termasuk kategori sedang, sedangkan kelompok kontrol memperoleh nilai masing-masing sebesar 0,29 dan 0,27. Analisis statistik multivariat juga menunjukkan adanya perbedaan yang signifikan antara kedua kelompok. Meskipun ukuran efek yang dihasilkan masih relatif rendah, hasil penelitian ini menunjukkan bahwa integrasi Problem-Based Learning dalam media pembelajaran digital mampu memberikan dampak positif terhadap peningkatan kemampuan pemecahan masalah dan keterampilan proses sains peserta didik dalam pembelajaran sains.

**Kata Kunci:** *LKPD Elektronik, Problem Based Learning, Kemampuan Pemecahan Masalah, Research and Development, Keterampilan Proses Sains*

**ABSTRACT**

The persistent challenges in developing students' higher-order thinking skills in science learning indicate that the integration of technology and pedagogy has not been optimally implemented. This study aimed to develop and evaluate a Problem-Based Learning (PBL)-based electronic student worksheet (e-LKPD) in terms of its validity, practicality, and effectiveness in improving students' problem-solving abilities and science process skills. The study employed a Research and Development (R&D) approach combined with a quasi-experimental design involving experimental and control groups. The research stages included product development, expert validation, limited trials, and implementation in the learning process. The results showed that the developed PBL-based e-LKPD was categorized as highly

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valid and highly practical based on expert validation and positive user responses. In terms of effectiveness, the experimental group demonstrated greater improvement than the control group, with N-Gain scores of 0.60 for problem-solving ability and 0.50 for science process skills, both categorized as moderate, while the control group obtained scores of 0.29 and 0.27, respectively. Multivariate statistical analysis also confirmed significant differences between the two groups. Although the resulting effect sizes were relatively low, the findings indicate that the integration of Problem-Based Learning into digital learning media provides a positive contribution to improving students' problem-solving abilities and science process skills in science education.

**Kata Kunci:** *LKPD Elektronik, Problem Based Learning, Problem Solving Ability, Research and development, Science Process Skill*

## INTRODUCTION

The development of students' higher-order thinking skills has become one of the major concerns in science education in the 21st century. However, students' problem-solving abilities in Indonesia are still categorized as relatively low, particularly in science and mathematics learning. Research indicates that students often experience difficulties in identifying problems, designing solution strategies, and evaluating the results of their investigations. This condition reflects that learning practices still tend to emphasize memorization rather than analytical and critical thinking processes. According to Putri and Juandi (2022), students' mathematical problem-solving abilities are strongly influenced by internal factors such as self-efficacy and learning confidence. In addition, Hamzah et al. (2023) emphasized that metacognitive-based learning is essential for improving higher-order thinking skills (HOTS) in modern education.

The low achievement of Indonesian students in international assessments also indicates the need for innovation in science learning. The results of PISA and TIMSS demonstrate that students' literacy, reasoning, and problem-solving competencies are still below international standards. These findings show that many students have not yet mastered critical and analytical thinking skills in solving contextual scientific problems. According to Harto and Hawa (2025), improving literacy competence and scientific reasoning should become a primary focus in Indonesian education reform. Science learning should therefore encourage students to actively construct knowledge through investigation and inquiry processes. Such conditions indicate the necessity of implementing innovative learning approaches that support students' active engagement and critical thinking development.

One important competency closely related to scientific reasoning is science process skills. These skills include observing, classifying, predicting, interpreting data, formulating hypotheses, and communicating findings scientifically. Science process skills are considered fundamental competencies because they enable students to understand scientific concepts through direct experience and experimentation. According to Wahyuni and Hambali (2024), science process skills significantly contribute to improving students' science learning outcomes. However, previous studies reported that the implementation of science process skills in science classrooms remains suboptimal due to limited innovative instructional practices and inadequate learning resources. Research conducted by Rahma and Wahyuni (2025) also revealed that junior secondary school students still experience difficulties in conducting experiments and interpreting scientific data.

The integration between problem-solving ability and science process skills is essential in supporting students' higher-order thinking development. Students who possess good problem-solving abilities tend to demonstrate more systematic thinking patterns when



identifying problems, analyzing information, and drawing conclusions. Likewise, science process skills enable students to investigate scientific phenomena through evidence-based reasoning. According to Dinova and Mustika (2025), creativity and HOTS-oriented science learning significantly influence students' ability to solve scientific problems. Furthermore, Siswanto (2023) explained that science learning in the 21st century should integrate problem-solving activities with contextual and socioscientific issues. Therefore, learning innovation is needed to facilitate both competencies simultaneously within meaningful classroom activities. Despite the importance of these competencies, learning practices in schools are still dominated by conventional approaches. Teachers frequently implement teacher-centered learning, resulting in limited student participation during classroom activities. This condition reduces opportunities for students to develop critical thinking, collaboration, and inquiry skills independently. According to Firmansyah and Jiwandono (2022), many teachers still tend to apply teacher-centered learning rather than student-centered learning approaches. In addition, the worksheets commonly used in schools are still dominated by lower-order thinking skill (LOTS) questions that do not adequately stimulate analytical and problem-solving abilities. Consequently, instructional materials need to be redesigned to become more interactive, contextual, and technology-based in accordance with the demands of 21st-century education.

The advancement of digital technology provides opportunities to develop innovative learning media such as electronic student worksheets (E-LKPD). Digital teaching materials are considered more interactive and flexible because they can integrate multimedia elements, animations, videos, and online learning activities. According to Darmayanti and Amalia (2024), digital teaching materials have significant potential to improve students' engagement and learning effectiveness in elementary and secondary education. Research by Firtsanianta and Khofifah (2022) also demonstrated that E-LKPD assisted by Liveworksheet effectively improves students' learning outcomes. Moreover, technology integration in science learning has become increasingly relevant in supporting interactive and student-centered instruction. Therefore, the development of E-LKPD integrated with innovative learning models is highly necessary to support science learning improvement.

One learning model that is considered effective in facilitating problem-solving and scientific investigation is Problem-Based Learning (PBL). PBL encourages students to actively solve contextual problems through collaborative inquiry and investigation activities. This model also supports the development of critical thinking, creativity, communication, and collaboration skills as part of 21st-century competencies. According to Faudziah and Budiman (2023), the implementation of PBL significantly improves students' critical thinking abilities. Similar findings were also reported by Yanti et al. (2025), who found that PBL effectively enhances students' critical and problem-solving skills in learning activities. However, studies integrating PBL-based E-LKPD to simultaneously improve problem-solving abilities and science process skills, particularly on ecology and biodiversity topics, are still limited. Therefore, this study aims to develop and evaluate a PBL-based E-LKPD designed to improve students' problem-solving abilities and science process skills within a technology-integrated science learning environment.

## **RESEARCH METHOD**

This study employed a Research and Development (R&D) method to develop a Problem-Based Learning (PBL)-based electronic student worksheet (E-LKPD) aimed at improving students' problem-solving abilities and science process skills in science learning. The development procedure adopted the Four-D (4-D) model consisting of Define, Design,



Develop, and Disseminate stages. In the Define stage, preliminary analyses were conducted, including learner analysis, task analysis, concept analysis, and formulation of learning objectives. The Design stage involved preparing the research instruments and designing the initial draft of the PBL-based E-LKPD. The Develop stage included expert validation, product revision, limited trials, and field testing to evaluate the practicality and effectiveness of the developed product. Finally, the Disseminate stage was conducted through implementation in schools and dissemination of the research findings through academic publications and presentations.

The research was conducted at SMP Negeri 14 Yogyakarta during the 2022/2023 academic year. The participants consisted of seventh-grade students, involving 32 students in the limited trial and 66 students in the field trial selected through cluster random sampling. The field trial applied a nonequivalent control group design consisting of an experimental class using the PBL-based E-LKPD and a control class using conventional learning materials. Data were collected using expert validation sheets, teacher and student response questionnaires, observation sheets, and multiple-choice pretest–posttest instruments to measure problem-solving abilities and science process skills. The collected data were analyzed using descriptive and inferential statistics. Product validity and practicality were analyzed descriptively, while effectiveness was measured using N-gain, MANOVA, and effect size analysis at a significance level of 0.05.

## **RESULT AND DISCUSSION**

This section presents the results and discussion of the study regarding the development and implementation of a Problem-Based Learning (PBL)-based electronic student worksheet (e-LKPD) in science learning. The findings are organized to provide a comprehensive overview of the product development outcomes, including validity, practicality, and effectiveness in improving students' problem-solving abilities and science process skills. The results are presented first in a systematic manner based on the stages of product evaluation, supported by tables to clarify the quantitative findings obtained during the research process. Furthermore, the discussion elaborates on the interpretation of the findings in relation to relevant theories and previous studies. Each result is analyzed to explain its meaning within the context of learning science in the 21st century, particularly in relation to the integration of digital learning media and the Problem-Based Learning model. This section also highlights how the developed e-LKPD contributes to improving student-centered learning, as well as its implications for classroom practice. In addition, the discussion connects the empirical findings with existing research to provide stronger justification for the effectiveness and limitations of the developed product.

### **Results**

The results of this study indicate that the developed Problem-Based Learning (PBL)-based electronic student worksheet (e-LKPD) fulfilled the criteria of validity, practicality, and effectiveness in improving students' problem-solving abilities and science process skills. The product development process was conducted systematically through validation, practicality testing, and effectiveness testing stages. The implementation of the developed e-LKPD was carried out in science learning activities involving experimental and control classes. The findings demonstrate that the integration of digital learning media with the PBL model positively contributed to students' learning activities and competencies. Overall, the developed product showed promising potential to support technology-integrated science learning in junior

secondary schools. The validity of the developed product was assessed by content and media experts to determine the feasibility of the instructional module, electronic worksheet, and research instruments. The validation process evaluated several aspects, including content appropriateness, instructional structure, language clarity, graphical design, accessibility, and construct validity of the instruments. The results showed that all developed components achieved high validity scores and were categorized as excellent or valid. These findings indicate that the developed e-LKPD met the required standards for implementation in science learning activities. The complete results of product validation are presented in Table 1.

**Table 1. Product Validation Results**

Component	Assessed Aspects	Score/Index	Category
Instructional Module	Content alignment, structure, and language	34/36	Excellent
Electronic LKPD (Content)	Content quality, presentation, and characteristics	35/37	Excellent
Electronic LKPD (Media)	Graphics, technical design, and accessibility	17/17	Excellent
Problem-Solving Instrument	Content validity, construct validity, and language	0.83	Valid
Science Process Skills Instrument	Content validity, construct validity, and language	0.88	Valid

Based on Table 1, the instructional module obtained a score of 34 out of 36 and was categorized as excellent. The content aspect of the electronic LKPD achieved a score of 35 out of 37, while the media aspect obtained a perfect score of 17 out of 17. In addition, the problem-solving ability instrument and science process skills instrument achieved validity indices of 0.83 and 0.88, respectively, indicating that both instruments were valid for data collection purposes. These results demonstrate that the developed product possessed appropriate instructional quality, visual design, and assessment feasibility. Therefore, the developed PBL-based e-LKPD was considered suitable for implementation in science learning activities.

The practicality of the developed e-LKPD was evaluated through teacher and student response questionnaires during the learning implementation process. The findings showed that both teachers and students responded positively to the use of the electronic worksheet in classroom activities. Students reported that the e-LKPD was easy to access, visually attractive, and helpful in understanding science concepts and completing learning tasks. Teachers also indicated that the developed worksheet supported classroom interaction and increased student participation during problem-solving activities. The student response rate reached 92.74%, indicating that the developed product was categorized as highly practical for classroom implementation.

The effectiveness of the developed e-LKPD was measured using N-Gain analysis to determine the improvement in students' problem-solving abilities and science process skills after the implementation of the learning intervention. The analysis results showed that the experimental class achieved higher improvement compared to the control class in both measured variables. Students in the experimental class demonstrated better performance in identifying problems, conducting investigations, interpreting findings, and drawing conclusions. In contrast, students in the control class showed relatively lower improvement

during the learning process. The complete results of the N-Gain analysis are presented in Table 2.

**Table 2. N-Gain Results of Problem-Solving Ability and Science Process Skills**

Class/Variable	N-Gain Category	
Control Class – Problem-Solving Ability	0.29	Low
Control Class – Science Process Skills	0.27	Low
Experimental Class – Problem-Solving Ability	0.60	Moderate
Experimental Class – Science Process Skills	0.50	Moderate

Based on Table 2, the experimental class obtained an N-Gain score of 0.60 for problem-solving ability and 0.50 for science process skills, both categorized as moderate improvement. Meanwhile, the control class achieved N-Gain scores of 0.29 and 0.27, which were categorized as low improvement. These findings indicate that the implementation of the PBL-based e-LKPD contributed more effectively to students' competency improvement compared to conventional learning. Furthermore, the MANOVA analysis revealed a significant simultaneous difference between the experimental and control groups with a significance value below 0.05. The findings suggest that the developed e-LKPD positively affected both problem-solving abilities and science process skills simultaneously.

## Discussions

The findings of this study demonstrate that the developed Problem-Based Learning (PBL)-based electronic student worksheet (e-LKPD) fulfilled the criteria of validity and feasibility for science learning implementation. The high validation results indicate that the developed product possessed appropriate content quality, instructional structure, language clarity, and media design. This finding confirms that integrating digital technology with well-structured instructional design can produce effective and relevant learning media for 21st-century education. The result is consistent with the study conducted by Armanda et al. (2025), which reported that digital learning media achieved high validity when developed through systematic instructional design procedures. Similarly, Sari et al. (2022) found that PBL-based E-LKPD effectively supported higher-order thinking skills through valid and structured learning activities in science education.

The practicality findings revealed that the developed e-LKPD was categorized as highly practical based on positive responses from both teachers and students. Students perceived that the electronic worksheet was easy to use, visually attractive, and capable of supporting independent learning activities during science instruction. Teachers also indicated that the developed e-LKPD facilitated classroom interaction and encouraged students to participate more actively in problem-solving activities. These findings are aligned with Nisa et al. (2024), who explained that digital teaching materials provide more flexible and interactive learning experiences compared to conventional printed materials. In addition, Milala et al. (2022) emphasized that digital learning media contribute significantly to improving practicality, usability, and learning effectiveness in classroom implementation.

The improvement in students' problem-solving abilities indicates that the integration of the PBL model within the e-LKPD successfully facilitated analytical and critical thinking processes during science learning. Through contextual problems and collaborative activities, students were encouraged to identify problems, analyze information, and formulate solutions



systematically. The moderate N-Gain results obtained by the experimental class demonstrate that the developed e-LKPD contributed positively to enhancing students' higher-order thinking skills. These findings are consistent with the study by Ramadhani et al. (2024), which reported that Problem-Based Learning effectively improves students' mathematical problem-solving abilities. Likewise, Sari et al. (2022) stated that the implementation of PBL-based E-LKPD can enhance students' HOTS through active learning experiences centered on real-life problem-solving situations.

The findings also indicate that the developed e-LKPD contributed positively to improving students' science process skills. The implementation of observation, investigation, data interpretation, and problem-analysis activities within the worksheet enabled students to engage more actively in scientific inquiry processes. Students in the experimental class demonstrated better abilities in conducting scientific activities compared to students in the control class. This condition suggests that the integration of digital media with inquiry-oriented instructional models can support the development of science process skills effectively. The results are in line with Fridayanti et al. (2022), who found that interactive audio-visual learning media significantly improved students' learning engagement and science understanding. In addition, Yuliasari (2024) explained that STEM-based science learning contributes positively to the development of 21st-century competencies, including scientific investigation and problem-solving skills.

The significant simultaneous improvement in problem-solving abilities and science process skills indicates that the developed PBL-based e-LKPD supported the development of multiple competencies in an integrated manner. This finding reflects that digital learning media integrated with innovative learning models can create more meaningful and student-centered learning experiences. Students were not only encouraged to understand concepts theoretically but were also actively involved in inquiry, collaboration, communication, and critical thinking activities during the learning process. These findings are supported by Sahronih et al. (2023), who reported that the integration of digital technology in science learning enhances student engagement and supports active learning environments. Furthermore, Nurmalisa et al. (2023) emphasized that digital learning media play an important role in accommodating diverse learning styles and improving students' motivation and participation in classroom activities.

Despite the positive findings, this study also identified several limitations that may have influenced the overall research outcomes. The relatively short duration of implementation may have limited the optimization of students' higher-order thinking skills and science process skills. In addition, several learning activities within the developed e-LKPD were still relatively structured, resulting in limited opportunities for deeper scientific inquiry and independent exploration. Technical factors such as internet connectivity, device availability, and variations in students' digital literacy also potentially affected the implementation process. These findings are consistent with Fitriainingsih et al. (2025), who explained that digital literacy readiness remains an important factor influencing the effectiveness of interactive E-Worksheets in schools. Similarly, Juneda et al. (2025) reported that teachers' experiences in implementing digital media are closely related to technological readiness and students' motivation during science learning activities.

## CONCLUSION

The development of the Problem-Based Learning (PBL)-based electronic student worksheet (e-LKPD) demonstrates that the integration of digital learning media with innovative instructional models can support more meaningful and student-centered science learning. The



developed product fulfilled the criteria of validity, practicality, and effectiveness, indicating that it is feasible for implementation in science education. The findings reveal that the use of the PBL-based e-LKPD contributed to the improvement of students' problem-solving abilities and science process skills through active engagement in contextual problem-solving and scientific investigation activities. These results confirm that technology-supported learning integrated with PBL can facilitate the development of higher-order thinking skills and scientific competencies needed in 21st-century education. In addition, the implementation of the e-LKPD encouraged students to participate more actively, collaboratively, and critically during the learning process.

Although the improvements obtained were categorized as moderate and the resulting effect sizes remained relatively low, the findings indicate that the implementation of PBL-based digital learning media has meaningful potential to improve students' cognitive and scientific skills when supported by appropriate instructional strategies and sufficient implementation time. The study also highlights the importance of integrating interactive digital media with inquiry-based learning activities to achieve more optimal learning outcomes in science education. Therefore, future research is recommended to develop more flexible and accessible e-LKPD designs, including offline-based platforms and broader integration of 21st-century competencies such as collaboration, communication, creativity, and digital literacy. Further studies with longer intervention periods and wider implementation contexts are also necessary to obtain more comprehensive evidence regarding the effectiveness of PBL-based digital learning media in science learning.

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