



Development of Deep Learning-Based E-LKPD in Physics Learning to Improve Critical Thinking and Creative Thinking Skills of High School Students

Linda Khairo^{1*}, Yohandri², Fatni Mufit², Emiliannur²

¹ Magister of Physics, Faculty of Mathematics and Natural Sciences, Padang State University, Padang, Indonesia.

² Department of Physics, Faculty of Mathematics and Natural Sciences, Padang State University, Padang, Indonesia.

Received: April 02, 2026

Revised: May 01, 2026

Accepted: June 25, 2026

Published: June 30, 2026

Corresponding Author:

Linda Khairo

lindakhairo@gmail.com

DOI: [10.29303/jppipa.v12i6.15156](https://doi.org/10.29303/jppipa.v12i6.15156)

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Abstract: The low critical and creative thinking skills of eleventh grade students at SMAN 1 Lembah Melintang on mechanical wave material, reaching only 38.20% and 47.10% respectively, indicate an urgent need for innovative teaching materials. This study aims to develop a Deep Learning-based Electronic Student Worksheet (E-LKPD) assisted by Heyzine on Mechanical Wave material to improve critical and creative thinking skills of high school students. The research used Research and Development (R&D) method with the Plomp model encompassing three phases: preliminary research, prototyping phase, and assessment phase. The E-LKPD integrates three pillars of Deep Learning: Meaningful Learning, Joyful Learning, and Mindful Learning. The results show that the developed E-LKPD: (1) was declared very valid with an average Aiken V value of 0.87; (2) was declared very practical with a score of 88.54% according to teachers and 84.32% according to students; and (3) proved very effective in improving critical thinking skills from 38.20% to 80.93% and creative thinking from 47.10% to 81.90%, with N-Gain values of 0.691 (medium) and 0.658 (medium) respectively. This Deep Learning-based E-LKPD is suitable as an innovative alternative teaching material in high school physics learning aligned with the demands of the Merdeka Curriculum.

Keywords: Creative thinking; Critical thinking; Deep learning; E-LKPD; Mechanical wave

Introduction

The quality of education today needs continuous improvement to produce students with 21st century skills. The demands of the world of work and modern society require individuals to think critically in solving problems and produce creative solutions. Therefore, the learning process must be adapted to the standards and needs of the 21st century so that graduates are ready to face increasingly complex global challenges (Ashari Hamzah et al., 2022).

Critical and creative thinking skills are essential for students in physics learning. Physics learning ideally requires students not only to master theoretical concepts, but also to apply critical and creative thinking

skills in solving complex physics problems (Parwati et al., 2026; Haris et al., 2025; Talamás-Carvajal et al., 2024; Lukman et al., 2025). Effective learning processes should actively involve students in concept discovery, supplemented by interactive learning media that support the development of 21st century skills, and use comprehensive scientific approaches to facilitate exploration and innovation (Chastanti et al., 2017; Barus et al., 2020; Syafril & Aini, 2022)

Preliminary research conducted at SMAN 1 Lembah Melintang revealed that although the school has implemented the Merdeka Curriculum, physics learning was still less engaging for students. Based on interviews with physics teacher Wahdina, S.Pd., the limitation of teaching material facilities and the absence of a physics

How to Cite:

Khairo, L., Yohandri, Mufit, F., & Emiliannur. (2026). Development of Deep Learning-Based E-LKPD in Physics Learning to Improve Critical Thinking and Creative Thinking Skills of High School Students. *Jurnal Penelitian Pendidikan IPA*, 12(6), 65-72. <https://doi.org/10.29303/jppipa.v12i6.15156>

practicum class for grade XI were key obstacles. The analysis results showed that critical thinking ability was only at 38.20% and creative thinking at 47.10% – both in the low category.

Previous studies have attempted to address physics learning problems through various media and learning model developments. Hadyan et al. (2025) found that integrating project-based and inquiry learning in a Deep Learning approach was able to drive student engagement and critical thinking (Sofa et al., 2025). Musdi et al. (2026) emphasized that Deep Learning is based on three main pillars: mindful, meaningful, and joyful learning, which proved effective in improving the quality of digital learning tools (Al-Zahra, 2026; Sumarni & Okyranida, 2025; Putri et al., 2024). Furqon et al. (2025) and Ramadhani et al. (2026) developed a multirepresentation-based E-LKPD assisted by Liveworksheet that was declared very valid and very practical for physics learning (Burnama & Hariyono, 2024).

Electronic Student Worksheets (E-LKPD) offer significant potential to facilitate active, interactive, and meaningful learning. The Heyzine platform provides interactive features including fillable columns, embedded videos, simulations, and direct feedback that can support students learning independently. The integration of the Deep Learning approach in E-LKPD is expected to stimulate critical and creative thinking skills more optimally compared to conventional teaching materials (Prihantoro, 2025; Aisyah et al., 2020; Mukaromah & Inayah, 2025; Mulyani et al., 2025). Based on this background, the present research develops a Deep Learning-based E-LKPD on Mechanical Wave material to improve critical and creative thinking skills of eleventh grade high school students.

Method

This research is a Research and Development (R&D) study using the Plomp development model, which consists of three phases: (1) preliminary research, (2) prototyping phase (development phase), and (3) assessment phase. The research was conducted at SMAN 1 Lembah Melintang during the 2025/2026 academic year.

The preliminary research phase included needs analysis, student characteristics analysis, curriculum and material analysis, and teaching material analysis. The prototyping phase involved product design and formative evaluation consisting of self-evaluation, validity testing, and practicality testing (Kahar et al., 2021; Jin, 2022). The assessment phase involved

effectiveness testing of the E-LKPD (Erlangga & Fitriyah, 2025; Nabila et al., 2026).

The validity testing subjects were three physics lecturers from Universitas Negeri Padang who acted as expert validators. Practicality testing involved two physics teachers and 35 grade XI IPA students at SMAN 1 Lembah Melintang. Effectiveness testing involved 25 grade XI IPA students at SMAN 1 Lembah Melintang.

Research instruments included: (1) validity sheets assessed using Aiken V formula with validity criteria $V > 0.60$; (2) practicality questionnaires analyzed using the formula $P = (f/N) \times 100\%$ referring to Riduwan (2011) with scores $\geq 81\%$ classified as very practical; and (3) pretest-posttest instruments consisting of 20 essay items measuring critical thinking (Facione indicators: interpretation, analysis, evaluation, inference, explanation, and self-regulation) and creative thinking (Torrance indicators: fluency, flexibility, originality, and elaboration). Effectiveness data were analyzed using the N-Gain formula with categories: high ($g \geq 0.70$), medium ($0.30 \leq g < 0.70$), and low ($g < 0.30$).

Result and Discussion

Preliminary Research Phase

The preliminary research phase resulted in needs analysis data, student characteristics, curriculum analysis, and teaching material analysis at SMAN 1 Lembah Melintang. The needs analysis showed an average learning resource achievement of 58.3% (fair category) and teaching material average of 68.75% (fair category). Analysis of student characteristics revealed that learning motivation was at 54% (low), learning interest at 50% (low), and learning attitude at 63.1% (fair). Critical thinking skills were only at 38.2% and creative thinking at 47.1%, both in the low category. These findings confirm the urgent need to develop an innovative, interactive, and structured E-LKPD based on the Deep Learning approach. Curriculum analysis showed that Mechanical Wave material in the Merdeka Curriculum Phase F aligned well with the three pillars of Deep Learning (Mustapa & Arbie, 2026; Suardin et al., 2025; Nurhalisa et al., 2026; Salsabilla et al., 2024).

Product Design (Prototyping Phase)

Based on preliminary research, the E-LKPD was designed with nine main components: (1) cover, (2) preface, (3) table of contents, (4) usage instructions, (5) learning achievement and objectives, (6) learning activities with Deep Learning approach, (7) evaluation, (8) learning reflection, and (9) digital portfolio. The E-LKPD covers 4 learning sessions on Mechanical Wave material integrated with three Deep Learning pillars.

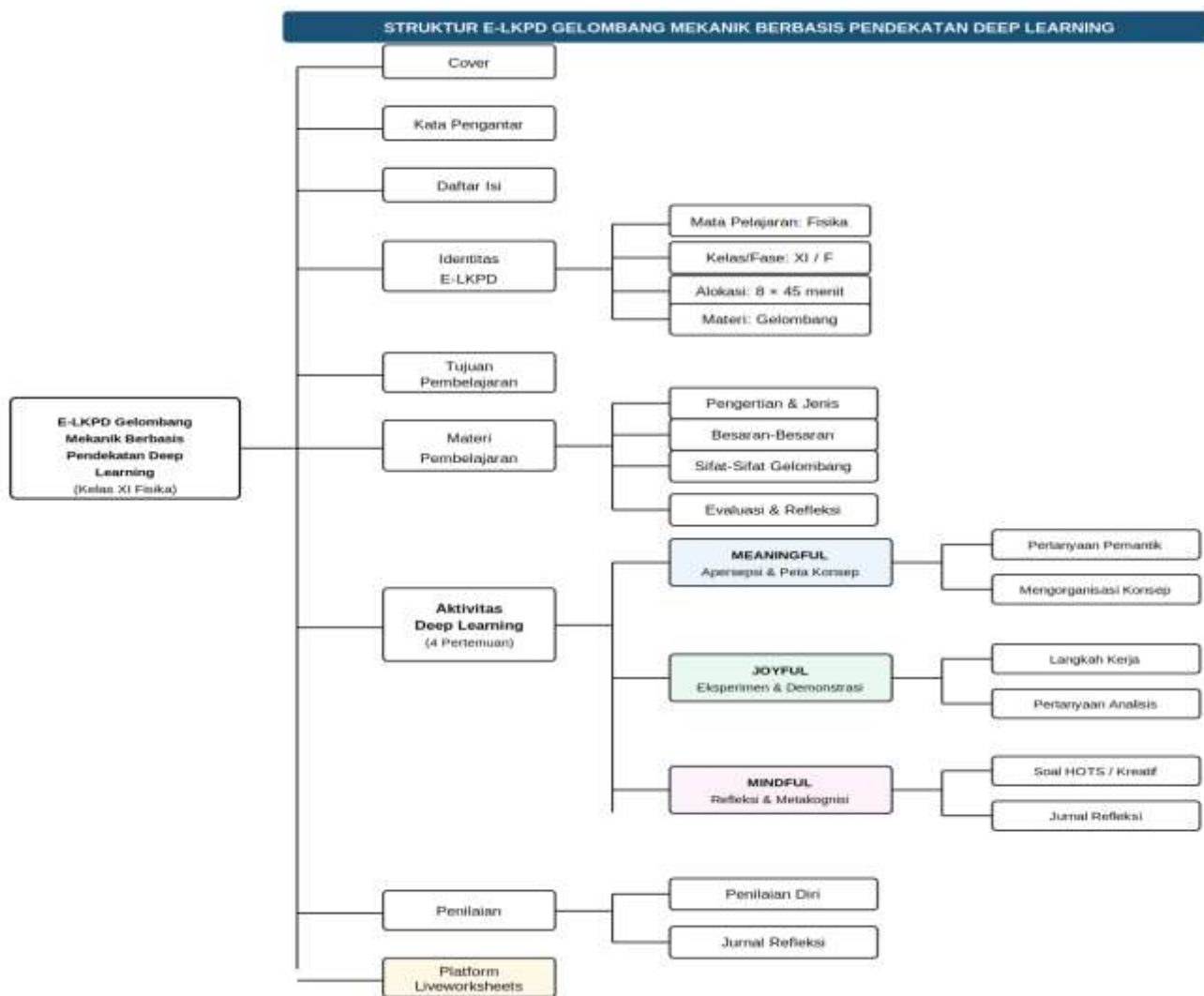


Figure 1. Structural design of deep learning-based E-LKPD



Figure 2. Meaningful learning stage in E-LKPD



Figure 3. Joyful learning stage in E-LKPD



Figure 4. Mindful learning stage in E-LKPD

In the Meaningful Learning stage, apperception activities based on real-life phenomena (water ripples, guitar sounds, beach waves) and concept maps are provided to encourage students to connect physics concepts with their experiences. The Joyful Learning stage is realized through simple demonstrations using ropes and slinkies, experiments observing wave properties in water, and divergent thinking challenges. The Mindful Learning stage is presented through deep reflection questions, HOTS problems, self-assessment, and a reflection journal to encourage students to metacognitively evaluate their thinking process.

Validity Results

Validity testing was conducted by three expert validators who are physics lecturers at Universitas Negeri Padang. Assessment was carried out on five aspects using the Aiken V formula. The validity results are presented in Table 1.

Table 1. Validity Values of E-LKPD Prototype

Aspect	Average Aiken V	Category
Material Substance	0.97	Valid
Learning Design	0.82	Valid
Visual Communication Display	0.86	Valid
Integration of Deep Learning Approach	0.85	Valid
Development of Critical & Creative Thinking	0.85	Valid
Overall Average	0.87	Valid

Based on Table 1, all assessment aspects obtained Aiken V values above 0.60 with an overall average of 0.87, categorized as Valid. The material substance aspect obtained the highest value (0.97), indicating that the Mechanical Wave content presented in the E-LKPD is highly consistent with Merdeka Curriculum Phase F Learning Achievement. The learning design aspect obtained the lowest value (0.82), indicating the need for further alignment between learning objectives, activities, and assessment (constructive alignment). These results are consistent with Costadena and Suniasih (2022) who developed an interactive E-LKPD with very valid validity, and Septiaahmad et al. (2020) who produced an E-LKPD with validity of 88.4%.

Based on validator suggestions, revisions were made including: (1) reconstruction of evaluations based on critical and creative thinking indicators, (2) updating curriculum terminology ("Profil Pelajar Pancasila" to "Dimensi Profil Lulusan"), (3) alignment of objectives-activities-assessment (constructive alignment), and (4) strengthening visual media and videos. After revision, the E-LKPD was declared valid and feasible to proceed to practicality testing.

Practicality Results

Practicality testing was conducted by two physics teachers and 35 students of grade XI IPA SMAN 1 Lembah Melintang. The practicality results according to teachers are presented in Table 2.

Table 2. E-LKPD Practicality Values According to Teachers

Assessment Aspect	Value P (%)	Category
Ease of Use	87.50	Very Practical
Practicality	87.50	Very Practical
Learning Implementation	91.67	Very Practical
Time Effectiveness	87.50	Very Practical
Average	88.54	Very Practical

Based on Table 2, the E-LKPD was in the very practical category according to teachers with an average value of 88.54%. The learning implementation aspect obtained the highest value of 91.67%, showing that the E-LKPD can be implemented well according to the learning plan. The practicality results according to students are presented in Table 3.

Table 3. E-LKPD Practicality Values According to Students

Assessment Aspect	Value P (%)	Category
Ease of Use	82.86	Very Practical
Practicality	84.29	Very Practical
Display Attractiveness	86.43	Very Practical
Learning Motivation	83.71	Very Practical
Average	84.32	Very Practical

Based on Table 3, the E-LKPD was in the very practical category according to students with an average value of 84.32%. The display attractiveness aspect obtained the highest value of 86.43%, indicating that the Heyzine-based interactive E-LKPD design with a combination of colors, images, videos, and interactive features successfully attracted student attention. The overall practicality average from teachers and students was 86.43%, categorized as very practical. These findings are consistent with Jati et al. (2024) who developed a Problem Solving-based E-LKPD assisted by Liveworksheet in the very practical category, and Furqon et al. (2025) who produced a multirepresentation-based E-LKPD that was very valid and very practical.

Effectiveness Results

Effectiveness testing was conducted on 25 students using pretest and posttest. Critical thinking skills were measured based on six (Facione, 2013) indicators. The effectiveness results for critical thinking skills are presented in Table 4.

Table 4. E-LKPD Effectiveness Values on Students' Critical Thinking Skills

Critical Thinking Indicator	Pretest (%)	Posttest (%)	Increase (%)	Category
Interpretation	40.00	82.40	42.40	Very Effective
Analysis	38.80	81.60	42.80	Very Effective
Evaluation	36.40	79.20	42.80	Effective
Inference	38.00	80.80	42.80	Effective
Explanation	39.20	83.20	44.00	Very Effective
Self-Regulation	36.80	78.40	41.60	Effective
Average	38.20	80.93	42.73	Very Effective

Based on Table 4, critical thinking skills showed significant improvement after using the Deep Learning-based E-LKPD, from a pretest average of 38.20% (less effective) to a posttest average of 80.93% (very effective), with an average increase of 42.73%. The Explanation indicator showed the highest increase of 44.00%, while Self-Regulation showed the lowest increase of 41.60%. N-Gain analysis showed an overall value of 0.691

(medium category based on Hake, 1999), with Interpretation ($g = 0.707$) and Explanation ($g = 0.724$) reaching the high category.

Creative thinking skills were measured based on four indicators: fluency, flexibility, originality, and elaboration (Alabbasi et al., 2022). The effectiveness results for creative thinking skills are presented in Table 5.

Table 5. E-LKPD Effectiveness Values on Students' Creative Thinking Skills

Creative Thinking Indicator	Pretest (%)	Posttest (%)	Increase (%)	Category
Fluency	50.00	84.80	34.80	Very Effective
Flexibility	46.40	82.00	35.60	Very Effective
Originality	44.80	79.20	34.40	Effective
Elaboration	47.20	81.60	34.40	Very Effective
Average	47.10	81.90	34.80	Very Effective

Based on Table 5, creative thinking skills also showed significant improvement, from a pretest average of 47.10% (fairly effective) to a posttest of 81.90% (very effective), with an average increase of 34.80%. The Fluency indicator obtained the highest posttest value of 84.80%, while Originality obtained the lowest value of

79.20%. This indicates that students can more easily generate many ideas fluently, but still need more intensive training to produce truly original ideas. N-Gain analysis showed an overall value of 0.658 (medium category), with the highest on Fluency ($g = 0.696$) and lowest on Originality ($g = 0.623$).

Table 6. Summary of E-LKPD Effectiveness Testing Results

Thinking Skill	Pretest (%)	Posttest (%)	N-Gain	Category
Critical Thinking	38.20	80.93	0.691	Medium
Creative Thinking	47.10	81.90	0.658	Medium
Average	42.65	81.42	0.676	Medium

The overall N-Gain combined between critical and creative thinking skills was 0.676, categorized as medium but very close to the high category threshold ($g \geq 0.70$). These results prove that the use of the Deep Learning-based E-LKPD with Heyzine consistently improved both thinking skills.

The increase in critical thinking skills is caused by the Deep Learning approach that requires students to be active, reflective, and meaningful in building conceptual understanding (Feriyanto & Anjariyah, 2024; Pranata, 2024; Carli, 2025). The Meaningful Learning stage trains students to connect Mechanical Wave concepts with real-life phenomena and analyze inter-concept relationships, forming the basis for the growth of interpretation and analysis skills. The Joyful Learning stage trains students in collecting data through direct

demonstrations and experiments, actively processing information through analysis questions and HOTS problems, thereby improving evaluation and inference skills. The Mindful Learning stage trains students in systematically explaining reasoning results through reflection journals and self-assessment, encouraging metacognitive awareness (Hidayah & Hulyana, 2025; Sastrawati & Nizaar, 2025).

The increase in creative thinking skills was caused by E-LKPD activities that gave students space to explore freely and think divergently. In the Joyful Learning stage of Session 3, students directly experimented with observing wave properties in water and were asked to develop innovative ideas. In the Mindful Learning stage of Session 3, students were challenged to design technology-based solutions on mechanical wave

properties requiring originality and elaboration skills. In Session 4 through the divergent thinking challenge activity, students were trained to generate various

alternative ideas (fluency) and flexibly (flexibility) (Musdi & Afifah, 2026; Hikmah et al., 2021).

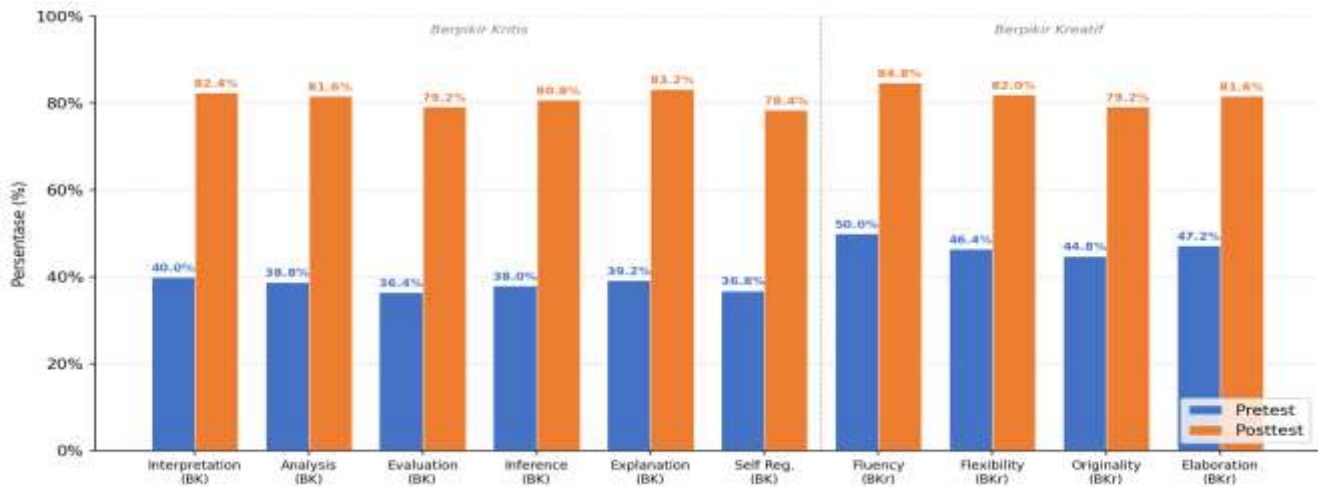


Figure 5. Comparison graph of pretest and posttest critical and creative thinking skills

Conclusion

Based on the research results, the Deep Learning-based E-LKPD on Mechanical Wave material for grade XI high school students has met the validity, practicality, and effectiveness criteria. (1) The E-LKPD was declared valid with an average Aiken V of 0.87. (2) The E-LKPD was declared very practical according to teachers (88.54%) and students (84.32%). (3) The E-LKPD was proven very effective in improving critical thinking skills from 38.20% to 80.93% (N-Gain = 0.691, medium) and creative thinking from 47.10% to 81.90% (N-Gain = 0.658, medium). The Deep Learning-based E-LKPD with Heyzine is feasible as an innovative alternative teaching material in high school physics learning in accordance with Merdeka Curriculum demands. It is recommended that future research expand the use of this E-LKPD to other physics materials and apply it to broader samples to confirm the generalizability of the results.

Acknowledgments

The authors thank the principal, physics teachers, and students of SMAN 1 Lembah Melintang who participated in this research. Gratitude is also extended to the validator lecturers from Universitas Negeri Padang for their valuable input.

Author Contributions

Conceptualization, L.K. and Y.; methodology, L.K.; validation, Y., F.M. and E.; formal analysis, L.K.; investigation, L.K.; resources, L.K.; data curation, L.K.; writing—original draft preparation, L.K.; writing—review and editing, Y., F.M. and E.; visualization, L.K.; supervision, Y. and F.M.; All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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