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Research Article

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Development of an electronic student worksheet based on REPIDS to improve students' science process skills and critical thinking

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ABSTRACT

Responding to the increasing demand for 21st-century skills, such as critical thinking and science processes, in solving environmental issues. The study aims to develop and evaluate REPIDS-based electronic student worksheets to improve students' science process skills and critical thinking in the topic of environmental pollution among vocational high school students. This study uses the Research and Development (R&D) method through the 4D model, which includes define, design, develop, and disseminate. This study was conducted up to the development stage and included part of the initial dissemination stage to assess the effectiveness of the product. The instruments used included expert validation sheets, classroom observation forms, and pre-test and post-test questions. Participants were tenth-grade vocational students selected through purposive sampling. Data were analyzed using percentage scores for validity and practicality, and normalized gain scores (N-gain) to measure effectiveness. The results of the study indicate that the developed REPIDS-based electronic student worksheet meets the criteria of validity (content aspect of 92%, language aspect of 85%, and design aspect of 90%), practicality (85%), and effectiveness (N-gain of 0.65, medium criteria) in improving science process skills and critical thinking. REPIDS-based electronic student worksheet is recommended for wider use in science education to support meaningful and skill-oriented learning.

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INTRODUCTION

The 21st-century education landscape emphasizes equipping students with essential skills to navigate an increasingly complex and digitalized world. Critical thinking, a core 21st-century competency, plays a pivotal role in fostering students' ability to analyze, evaluate, and solve problems. Numerous studies have highlighted the correlation between critical thinking skills and academic achievement in science education. For instance, students engaged in critical thinking activities exhibit deeper learning and higher engagement in science subjects (Pratiwi & Doyan, 2024). Moreover,

innovative teaching strategies that integrate technology, such as electronic student worksheets, have been shown to enhance learning outcomes significantly (Fatmawati et al., 2023).

Despite the promising potential of digital learning tools, challenges remain in their integration into educational practices, particularly in fostering critical thinking and scientific process skills. Traditional learning models often emphasize rote memorization, leaving little room for active student engagement or inquiry-based learning. At the research site, problems were found, including a lack of learning innovation focused on memorization, low students' science process skills and critical thinking abilities, as well as limited active student engagement and inadequate learning resources, making this research urgently needed to improve the quality of learning and student outcomes. Existing studies, such as Lubis (2023), primarily focus on the general effectiveness of digital tools but lack specific frameworks designed for addressing complex topics like environmental pollution. This gap underscores the need for a structured and interactive approach that leverages technology to promote higher-order thinking skills.

The study specifically focuses on improving science process skills and critical thinking among vocational high school students in the context of environmental pollution. By addressing these objectives, this study seeks to contribute to the body of knowledge on digital learning innovations while providing practical solutions for science education challenges. To improve students' critical thinking skills and science processes, this study developed and analyzed the REPIDS-based electronic student worksheet framework (Reading, Problem Solving, Investigating, Discussing, Sharing). This approach is designed to address challenges in science learning, especially those related to environmental pollution. By utilizing digital technology, the REPIDS-based electronic student worksheet is expected to encourage students to be more actively involved in the learning process, thereby improving their understanding of complex environmental issues.

The implementation of REPIDS-based electronic student worksheets allows students to access learning materials interactively and flexibly. Through features such as online discussions and collaboration in solving problems, students can develop critical thinking skills and science processes more effectively. This approach aligns with findings from Sinaga et al. (2024), which demonstrate that neuroscience-based interactive biology learning media significantly improve students' motivation and cognitive learning outcomes.. In addition, this study also highlights the importance of technology integration in science education to prepare students to face challenges in the digital era. By adopting a REPIDS-based electronic student worksheet, it is expected that students will not only gain scientific knowledge but also 21st-century skills such as problem solving, collaboration, and communication (Papagiannis & Pallaris, 2024). This approach is expected to be an effective learning model in the context of vocational education, especially in the fields of science and technology (Huang, 2025).

The potential of REPIDS-based electronic student worksheets to foster 21st-century skills aligns with recent educational trends emphasizing inquiry-based learning models. According to Cirkony et al. (2022), implementing structured inquiry frameworks in digital environments enables students to transition from passive recipients of information to active participants in their learning journey. This shift encourages deeper engagement with material, particularly in tackling real-world problems like environmental pollution. The focus on collaborative discussions and problem-solving activities in the REPIDS approach not only supports cognitive development but also strengthens interpersonal skills, which are critical in vocational education contexts.

Furthermore, leveraging digital tools for science education offers opportunities for integrating environmental awareness into the curriculum. Studies by García-Hernández et al. (2023) demonstrated that digital worksheets emphasizing sustainability themes significantly enhanced students'

understanding of ecological concepts and their ability to propose actionable solutions. This finding is particularly relevant to the REPIDS framework, which integrates investigative and sharing stages to promote critical reflection and idea exchange among students. By facilitating a holistic approach to learning, the REPIDS-based electronic student worksheet prepares students for both academic and societal challenges.

In addition, the flexibility and accessibility of REPIDS-based electronic student worksheets align with the needs of diverse learners in vocational high schools. Research by Denny et al. (2023) found that interactive and mobile-friendly learning platforms significantly reduced barriers to participation for students in rural areas, improving their academic performance and engagement. By incorporating multimedia elements and collaborative features, the REPIDS-based electronic student worksheet addresses these inclusivity challenges, ensuring that all students can benefit from high-quality science education regardless of location or socioeconomic background.

However, previous studies have not fully addressed the integration of structured digital learning frameworks in vocational high schools, particularly for complex topics such as environmental pollution. For instance, Lubis (2023) primarily examined the effectiveness of digital tools but lacked a specific focus on critical thinking and science process skills development. Similarly, Hajj-Hassan et al. (2024) explored the integration of digital tools in sustainability education, highlighting their potential to raise awareness and foster environmental responsibility, although without incorporating structured methodologies like REPIDS. Moreover, research by Papagiannis and Pallaris (2023) highlighted the importance of collaborative learning but did not assess its implementation within vocational high school science education. These gaps underscore the need for a structured and interactive approach that leverages technology to promote higher-order thinking skills in science education. Unlike previous studies that primarily focused on traditional or single-method interventions, this research integrates a blended learning model combining digital tools with inquiry-based strategies to enhance both science process skills and critical thinking in a more engaging and effective way.

Traditional learning models often emphasize rote memorization, leaving little room for active student engagement or inquiry-based learning. This issue is especially evident in vocational high schools, where science instruction frequently lacks innovation and fails to foster critical thinking or scientific inquiry. Preliminary observations at the research site revealed that students exhibited low performance in science process skills and critical thinking tasks, particularly in understanding complex issues such as environmental pollution. Learning materials used in the classroom were predominantly textbook-based, offering minimal opportunities for student interaction, problem-solving, or digital engagement. Furthermore, there was a noticeable absence of structured, technology-integrated learning tools that align with the demands of 21st-century education. These findings highlight a critical need for the development of innovative, student-centered digital learning resources.

Thus, the purpose of this study is to develop and analyze the effectiveness of REPIDS-based electronic student worksheets in improving vocational high school students' critical thinking and science process skills in the context of environmental pollution. The study aims to validate the tool's design, assess its practicality in real classroom settings, and evaluate its impact on student learning outcomes through quantitative analysis.

RESEARCH METHODS

This study employed a Research and Development (R&D) approach using the 4D development model introduced by Thiagarajan, which includes Define, Design, Develop, and Disseminate stages.

This approach aimed to produce a valid, practical, and effective REPIDS-based Electronic Student Worksheet to improve science process skills and critical thinking in vocational high school students. The research was conducted during the odd semester of the 2024/2025 academic year in SMK Ma'arif NU Kencong. The population consisted of all grade 10 students, and the sample comprised 30 students selected using purposive sampling. This sample was chosen based on their readiness to use digital learning tools and their familiarity with the environmental pollution topic (Creswell, 2018).

The instruments used in this study included validation sheets to assess the validity of the electronic student worksheet, observation sheets to evaluate practicality, and pre-test and post-test assessments were conducted to measure the effectiveness of the REPIDS-based Electronic Student Worksheet, using a total of 5 essay questions 5 targeting science process skills indicators and 5 addressing critical thinking skills indicators to ensure comprehensive evaluation aligned with the research objectives. Validation was conducted by three experts specializing in science education and digital learning. Observation sheets focused on students' engagement and ease of use, while the pre-test and post-test measured improvements in critical thinking and science process skills (Saputra et al, 2025).

Data collection involved multiple techniques. Validation sheets were distributed to experts, observation sheets were filled out by three independent observers, and tests were administered to students before and after using the electronic student worksheet. Data from the validation and observation sheets were analyzed quantitatively using percentage scores to determine validity and practicality. The effectiveness of the electronic student worksheet was evaluated using the N-gain formula to assess the improvement in students' pre-test and post-test results. A gain score of ≥ 0.7 indicated high effectiveness, while scores of 0.3–0.7 were categorized as moderate effectiveness (Hake, 1998). To measure the effectiveness of the REPIDS-based electronic student worksheet, the normalized gain (N-gain) score was calculated using the following formula. This formula helps determine the relative improvement in students' performance after using the learning tool. N-gain value criteria can be seen in Table 1.

$$N - Gain = \frac{Post\ test\ score - Pretest\ score}{Maximum\ score - Pretest\ score} \quad (1)$$

Table 1. N-Gain Value Criteria

N-Gain Score Range	Effectiveness Category
≥ 0.70	High Effectiveness
0.30 – 0.69	Moderate Effectiveness
< 0.30	Low Effectiveness

According to Hake (1998), a gain score of ≥ 0.7 indicates high effectiveness, while scores between 0.3–0.7 fall into the moderate effectiveness category, and scores below 0.3 are considered low in effectiveness. To assess students' science process skills, this study refers to specific indicators that represent essential scientific competencies students must develop. These indicators form the basis for both the design of the learning tools and the assessment instruments used in the pre-test and post-test evaluations. Table 2 presents the detailed indicators of science process skills used in this study. In addition to science process skills, this study also focuses on enhancing students' critical thinking skills, which are essential for problem-solving and scientific reasoning. The assessment of these skills is

guided by specific indicators that reflect various levels of cognitive complexity. These indicators are used to design the evaluation instruments and ensure alignment with the learning objectives. Table 3 outlines the critical thinking skill indicators applied in this research.

Table 2. Indicators for Science Process Skills

Indicators	Description
Observing	Collecting information about phenomena or objects using the senses.
Classifying	Grouping objects or phenomena based on shared characteristics.
Measuring	Quantitatively describing properties using appropriate tools.
Formulating Hypotheses	Making predictions or explanations based on prior knowledge.
Designing and Conducting Experiments	Planning and systematically executing investigations to test hypotheses.
Communicating	Sharing results, ideas, and conclusions through written or oral forms.

Table 3. Indicators for Critical Thinking Skills

Indicators	Description
Elementary Clarification	Focusing questions, analyzing arguments, and identifying main points.
Basic Support	Observing and evaluating the reliability of observations or data.
Inference	Drawing conclusions based on evidence and reasoning.
Advanced Clarification	Defining terms, identifying assumptions, and considering definitions.
Strategic and Tactical	Determining actions to solve problems and evaluating outcomes.

FINDING AND DISCUSSION

The development of this interactive learning media is based on the 4D model, which consists of four main stages define, design, develop, and disseminate. This model was chosen to ensure a systematic and structured approach in producing educational products that are aligned with the needs of students and the curriculum. The Define stage is a step taken to organize and define what is known as the needs analysis stage, in developing interactive learning media. In this step, an interview was conducted with one of the science teachers of class X at SMK Ma'arif NU Kencong. Based on the results of the interview with the teacher, who will be a guideline in analyzing the material, determining tasks, and analyzing learning objectives. The results of interviews with fellow teachers that have been carried out are that at the time of learning, electronic student worksheet media had not been implemented so that researchers can develop interactive media, one of the interactive media is electronic student worksheet media based on interactive REPIDS and how are the characteristics of class X students who will be respondents in the study. After knowing the characteristics of the students, it is continued by analyzing the material following the electronic student worksheet media. One of the materials for class X in the odd semester is about environmental pollution that will be used for research. Then it is continued by analyzing the tasks that will be given to students that refer to core competencies and basic competencies in environmental pollution material, and the curriculum applied in schools, namely the Merdeka Curriculum.

The design Stage is the initial design step for the media model or prototype. This initial design is adjusted to the define stage. This step is divided into the media selection process, format selection, and initial design. Based on the design stage, the electronic student worksheet has not been applied in the learning process, so the researcher chose the REPIDS-based electronic student worksheet. The format selection is done by analyzing the components found on the Live Worksheets website so that the researcher can determine the content to be used and also make an initial design for the media.

The develop (development) stage is carried out by creating a syllabus, ATP, learning modules, and developing REPIDS-based electronic student worksheet. The syllabus and ATP are arranged according to environmental pollution material on explaining phenomena scientifically, designing and evaluating scientific investigations, and translating data and evidence scientifically. The time allocation for the syllabus is 6 JP; the assessment is carried out in the knowledge domain only. The learning methods used include lecture methods, discussions and questions and answers, and conventional learning approaches. The assessment was carried out by testing students' critical thinking skills in the form of a pre-test and post-test, each with 5 questions, and through observations covering 5 indicators, namely focusing on and analyzing questions, observing observation reports, determining problem results, identifying assumptions, and determining an action. In the pre-test and post-test in the form of descriptions, learning activities in the learning module were divided into 3 meetings. Assessment of students' science process skills was measured using observation sheets carried out by three observers with criteria in accordance with the indicators of science process skills.

At the disseminate stage, this research was conducted in several vocational schools around the research location to disseminate the results of the development of the REPIDS-based electronic student worksheet. Dissemination was carried out by introducing this learning media to teachers and students through class-scale tests and group discussions regarding the effectiveness and ease of use in science learning on environmental pollution material. The teachers involved were given an understanding of how to access and implement the REPIDS-based electronic student worksheet, while students were tested in a classroom environment to see the response and improvement of science process skills.

The results of this study demonstrated that the REPIDS-based electronic student worksheet effectively improved the students' science process skills and critical thinking abilities. At this initial define stage, a thorough needs analysis was conducted to identify the learning problems faced by vocational high school students, particularly the lack of interactive and effective learning media to enhance critical thinking and science process skills. The learning objectives were clearly established, focusing on environmental pollution as the thematic context, ensuring the product would address specific curriculum goals and student needs.

Based on the define stage outcomes, the electronic student worksheet was carefully designed to integrate the REPIDS learning model with digital elements. Detailed lesson plans, worksheet formats, and assessment instruments were developed with attention to content accuracy, language clarity, and appealing visual design. Drafts of the worksheet were prepared and structured to facilitate active student engagement and inquiry. The product prototype was developed and then validated by three experts in science education and digital learning. Validation results showed an average score of 89%, placing the worksheet in the "very valid" category, confirming that the content, language, and design met educational standards. Practicality testing through observations and student responses yielded an average score of 85%, indicating the worksheet was easy to use, engaging, and relevant to the learning process.

The initial phase of the disseminate stage involved implementing the electronic student worksheet in real classroom settings to measure its effectiveness. Pre-test and post-test assessments were administered, and N-gain analysis produced an average score of 0.65, categorized as "medium" effectiveness. This indicates a significant improvement in students' critical thinking and science process skills after using the worksheet, demonstrating the product’s potential to enhance learning outcomes.

The validation results indicate that the REPIDS-based electronic student worksheet aligns with educational standards and effectively integrates science concepts, clear language, and visually

appealing design. Validation was conducted by three experts in science education and digital learning, focusing on three main aspects: content, language, and design. Each aspect received high scores, with an average validation score of 89%, categorized as "very valid". Validation results can be seen in Table 4.

Table 4. Validation Results

Aspects	Score (%)	Category
Content	92	Very Valid
Language	85	Very Valid
Design	90	Very Valid
Average	89	Very Valid

The validation results indicate that the REPIDS-based electronic student worksheet aligns with educational standards and effectively integrates science concepts, clear language, and visually appealing design. These aspects contribute to its high validity and potential for successful implementation. Practicality was evaluated through observation sheets and student feedback, which examined the ease of use, engagement, and relevance of the electronic student worksheet during the learning process. Practicality results can be seen in Table 5.

Table 5. Practicality Results

Aspects	Score (%)	Category
Ease of Use	88	Practical
Engagement	83	Practical
Relevance to Learning	84	Practical
Average	85	Practical

The results show that the electronic student worksheet is easy to navigate and effectively engages students. The interactive elements and structured activities ensure that students remain focused and motivated throughout the learning process. Effectiveness was measured using pre-test and post-test scores to calculate the N-gain, which reflects the improvement in students' critical thinking and science process skills.

Table 6. Effectiveness Results

No	Group Name	Pretest Average	Posttest Average	N-Gain (g)	N-Gain Category
1	Experimental Class	50	80	0.65	Medium

Table 5 shows the effectiveness results of the REPIDS-based Electronic Student Worksheet based on N-gain analysis. The experimental class obtained a pre-test average score of 50 and a post-test average score of 80, resulting in an N-gain score of 0.65, which falls into the "Medium" effectiveness category according to Hake's (1998) classification. This indicates a meaningful improvement in students' critical thinking and science process skills after using the developed worksheet, demonstrating its potential to enhance learning outcomes in vocational high school science education.

The findings align with previous studies emphasizing the benefits of digital tools in enhancing critical thinking and science process skills. However, this study revealed certain limitations. The medium N-gain score suggests room for improvement in tailoring the electronic student worksheet to cater to diverse learning styles. Future research could expand the sample size and include schools from urban

and suburban settings to validate the findings further. The strength of this study lies in its systematic application of the REPIDS framework, which provided students with clear guidance for analyzing complex environmental pollution topics. The integration of interactive elements, such as videos and simulations, also contributed to student engagement. However, additional features like adaptive assessments or gamification could enhance the tool's appeal and effectiveness. The findings support the role of technology in fostering 21st-century skills, particularly critical thinking and collaborative problem-solving. Another significant consideration is the scalability of such tools for broader educational contexts. Future iterations of the REPIDS-based electronic student worksheet could include features like cloud-based storage and mobile-friendly interfaces to facilitate wider adoption. Implementing feedback mechanisms, such as peer evaluations or automated hints, could further improve the REPIDS framework. Future research should explore the integration of adaptive and personalized features, expand the scope to diverse educational settings, and assess the long-term impact on student learning outcomes.

Science process skills are essential for engaging students in active learning and inquiry-based scientific investigations. Observing, as described by Bentley et al. (2007), involves collecting information about phenomena or objects using the senses, which forms the foundation for further analysis. Classifying, or grouping objects and phenomena based on shared characteristics, enhances students' ability to identify patterns and connections (Prasonine et al., 2023). Measuring skills allow students to quantitatively describe properties using appropriate tools, enabling precise data collection for scientific inquiry (Darman et al., 2024). Formulating hypotheses involves making predictions based on prior knowledge, encouraging logical reasoning (Nakamura & Sakuma, 2022). Designing and conducting experiments foster systematic problem-solving and the application of the scientific method, as emphasized by Öndeş (2025). Finally, communicating results through written or oral forms is critical for sharing findings and engaging in collaborative discussions (Wood, 2023).

Critical thinking skills, on the other hand, provide a structured approach for analyzing and solving complex problems. Ennis (1993) identifies elementary clarification as focusing questions, analyzing arguments, and identifying main points, which are fundamental to structured reasoning. Basic support involves observing and evaluating the reliability of data, a process that fosters informed decision-making (Jin et al., 2025; Romero & Ventura, 2024). Inference emphasizes drawing conclusions based on evidence and reasoning, which is essential for scientific investigations (Cain et al., 2021; Wang et al., 2022). Advanced clarification, such as defining terms and identifying assumptions, enables students to approach problems with precision and clarity (Pokhilenko et al., 2024). Lastly, strategic and tactical thinking focuses on determining actions and evaluating outcomes, equipping students with the skills to propose and assess solutions to real-world challenges.

The creation of interactive learning media is adjusted to the design at the design stage. The learning media is designed to combine various images, videos, materials, questions, and icons to make the learning media more interactive. The following is a display of REPIDS-based electronic student worksheet media created based on the design stage, which can be seen in Figure 1. The initial display section of the environmental pollution electronic student worksheet is designed to provide an informative and interesting introduction to students. On the home page, there are important elements such as a title that reflects the main theme, namely "environmental pollution", which is intended for grade X SMK students in the odd semester. The initial display design emphasizes simple but professional visual elements, containing identity information such as the name of the educational unit, class, semester, and related subjects.

The findings align with previous studies emphasizing the benefits of digital tools in enhancing critical thinking and science process skills. For example, Dermawan et al. (2020) interactive digital media, when integrated with structured learning frameworks, foster active student participation and meaningful learning experiences. The use of REPIDS stages, such as collaborative discussions and investigative tasks, aligns with Vygotsky's theory on the importance of social interaction in cognitive development.

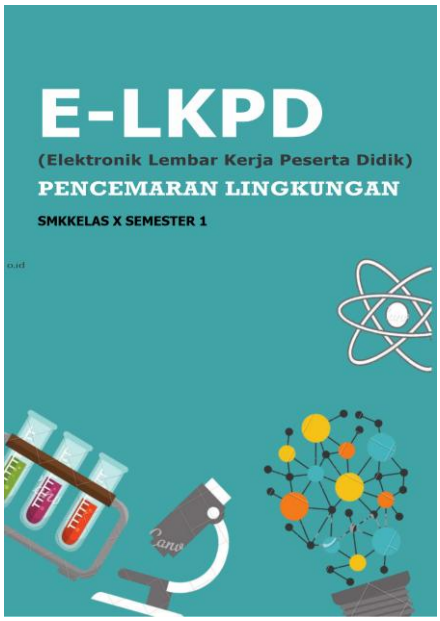

Figure 1. Cover Page of REPIDS-Based Electronic Student Worksheet

However, this study revealed certain limitations. The medium N-gain score (0.65) suggests room for improvement in tailoring the electronic student worksheet to cater to diverse learning styles. Similar findings by Lubis (2023) indicate that incorporating personalized feedback mechanisms can further enhance digital tools' effectiveness. Moreover, this study was conducted in a single vocational high school, limiting its generalizability. Future research could expand the sample size and include schools from urban and suburban settings to validate the findings further. The strength of this study lies in its systematic application of the REPIDS framework, which provided students with clear guidance for analyzing complex environmental pollution topics. The integration of interactive elements, such as videos and simulations, also contributed to the students' engagement. However, additional features like adaptive assessments or gamification could enhance the tool's appeal and effectiveness.

The findings support the role of technology in fostering 21st-century skills, particularly critical thinking and collaborative problem-solving. Utaminingsih et al. (2024) found that the use of digital tools, such as interactive worksheets, enhanced students' critical thinking abilities and improved their motivation and engagement. Similarly, integrating investigative activities within the REPIDS framework parallels findings by Putnam and Jones (2024), which emphasize that participation in interactive, hands-on science workshops significantly enhances students' understanding and long-term retention of scientific concepts. In addition, the study highlights the importance of integrating multimodal learning resources According to recent studies, incorporating visual, auditory, and kinesthetic elements in digital learning tools ensures a more inclusive approach that addresses varied learner preferences (Bouchey et al., 2025). The REPIDS-based electronic student worksheet's use of videos and simulations aligns

with these findings, though expanding these elements to include gamification or real-world case studies could further increase engagement.

Another significant consideration is the scalability of such tools for broader educational contexts. Recent studies by Wang and Liu (2023) demonstrated that digital infrastructure, when optimized for scalability, can bridge educational gaps between rural and urban schools by providing more equitable access to quality resources. Future iterations of the REPIDS-based electronic student worksheet could include features like cloud-based storage and mobile-friendly interfaces to facilitate wider adoption. The medium N-gain score observed in this study points to the need for iterative improvements in the tool's design. Research by Sayed et al. (2022) suggests that adaptive learning algorithms, which tailor content difficulty based on student performance, significantly boost the effectiveness of digital learning tools. Incorporating such features into the REPIDS-based electronic student worksheet could cater to individual learning needs and maximize its impact.

Moreover, the role of teacher facilitation in digital learning environments cannot be overlooked. As noted by Kaldaras et al. (2024), teacher-guided scaffolding and feedback embedded alongside computer simulations significantly enhance students' science understanding in digital learning environments. Providing professional development for teachers on effectively integrating REPIDS into their instruction would likely amplify the tool's benefits. Finally, fostering a feedback-rich environment could address one of the identified limitations of the study. Research by Kachak and Blyznyuk (2024) showed that real-time feedback in digital learning tools enables students to correct misconceptions and refine their critical thinking skills more effectively. Implementing feedback mechanisms, such as peer evaluations or automated hints, could further improve the REPIDS framework.

In summary, while this study demonstrates the potential of REPIDS-based electronic student worksheet in enhancing critical thinking and science process skills, there is significant room for growth. Future research should explore the integration of adaptive and personalized features, expand the scope to diverse educational settings, and assess the long-term impact on student learning outcomes. These enhancements would ensure that digital tools not only meet current educational demands but also prepare students for the challenges of the future.

CONCLUSION

This study aimed to develop and evaluate the effectiveness of a REPIDS (Reading, Problem Solving, Investigating, Discussing, Sharing)-based Electronic Student Worksheet to improve the critical thinking and science process skills of vocational high school students in the context of environmental pollution. The results of the research have met these objectives successfully. The development process, guided by the 4D model, resulted in a product with a very valid score of 89% from expert validation, indicating that the worksheet met the necessary standards for content accuracy, language clarity, and design. The practicality score of 85%, derived from student feedback and classroom observations, confirmed that the worksheet was easy to use, engaging, and suitable for the learning context. In terms of effectiveness, the worksheet achieved an N-gain score of 0.65, categorized as medium, which reflects a significant improvement in students' pre-test and post-test results, particularly in the areas of critical thinking and science process skills.

Based on these findings, the REPIDS-based Electronic Student Worksheet can be recommended as an effective digital learning tool for science education in vocational schools. It provides structured, interactive, and student-centered learning experiences that help students engage more deeply with scientific content while building essential 21st-century skills. Recommendations: For teachers, the

worksheet can serve as a ready-to-use resource to support inquiry-based learning and enhance classroom interactivity, particularly on complex topics like environmental pollution. For schools or educational institutions, it is recommended to integrate similar digital learning innovations into science curricula to improve student learning outcomes and engagement. For future researchers, it is advised to expand the scope of implementation across different subjects, educational levels, or with technological enhancements such as gamification or immersive simulations, to assess broader impacts and ensure continued relevance. In conclusion, the REPIDS-based electronic student worksheet has proven to be a valid, practical, and moderately effective educational tool that supports student learning and critical skill development in vocational science education.

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REFERENCES

Bentley, M. L., Ebert, E. S., & Ebert, C. (2007). *Teaching science with inquiry-based instruction* (2nd ed.). Pearson Education.

Bouchey, M., Dabbagh, N., & Kitsantas, A. (2025). A learning experience design framework for multimodal learning in early childhood education. *Smart Learning Environments, 12*, Article 76. https://doi.org/10.1186/s40561-025-00376-3

Cain, K., Oakhill, J., Barnes, M., & Bryant, P. (2021). Elaborative inference: A shared cognitive foundation for reading comprehension and mathematical reasoning. *Frontiers in Psychology, 12*, Article 709944. https://doi.org/10.3389/fpsyg.2021.709944

Cirkony, C., Tytler, R., & Hubber, P. (2022). Designing and delivering representation-focused science lessons in a digital learning environment. *Educational Technology Research Development, 70*(3), 881–908. https://doi.org/10.1007/s11423-022-10094-z

Creswell, J. W. (2018). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (6th ed.). Pearson Education.

Darman, D. R., Suhandi, A., Kaniawati, I., Samsudin, A., & Wibowo, F. C. (2024). Development and validation of scientific inquiry literacy instrument (SILI) using Rasch measurement model. *Education Sciences, 14*(3), Article 322. https://doi.org/10.3390/educsci14030322

Denny, D. P. S., Bakri, F., & Muliyati, D. (2023). High school physics student worksheets assisted by augmented reality: Enhancing problem solving skills. *Current Steam and Education Research, 1*(1), 33–40. https://doi.org/10.58797/cser.010105

Dermawan, D. D., Wuryandani, W., & Fadhilah, R. (2025). Improving critical thinking ability in elementary schools with interactive e-modules. *Online Journal of Communication and Media Technologies, 15*(2), e202513. https://doi.org/10.30935/ojcmt/16051

Ennis, R. H. (1993). Critical thinking assessment. *Theory into Practice*, *32*(3), 179–186. https://doi.org/10.1080/00405849309543594

Fatmawati, F., Rivaldi, M., & Suhaeni, S. (2023). Development of electronic student worksheets based on local potential to enhance students' science learning outcomes. *Jurnal IPA dan Pembelajaran IPA, 7*(1), 56–71. https://doi.org/10.24815/jipi.v7i1.29443

García-Hernández, A., García-Valcárcel Muñoz-Repiso, A., Casillas-Martín, S., & Cabezas-González, M. (2023). Sustainability in Digital Education: A Systematic Review of Innovative Proposals. *Education Sciences, 13*(1), 33. https://doi.org/10.3390/educsci13010033

Hajj-Hassan, M., Chaker, R., & Cederqvist, A.-M. (2024). Environmental Education: A Systematic Review on the Use of Digital Tools for Fostering Sustainability Awareness. *Sustainability, 16*(9), 3733. https://doi.org/10.3390/su16093733

Hake, R. R. (1998). Interactive-engagement vs. traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/10.1119/1.18809

Huang, F. (2025). Exploring a new model of undergraduate vocational education. *Vocational Technical Education*, 2(1). https://doi.org/10.54844/vte.2025.0869

Jin, R., Peng, Y., Wang, Z., Wang, J., Tang, J., & Zhang, M. (2025). Data-Driven Educational Decision-Making: How to Enhance Educational Quality and Management Efficiency. *Journal of Higher Education Research, 5*(6), 550. https://doi.org/10.32629/jher.v5i6.3385

Kachak, T., & Blyznyuk, T. (2024). Benefits of interactive learning for students' critical thinking skills improvement. *Journal of Pedagogical Research and New Understandings, 11*(1), 94–102. https://doi.org/10.15330/jpnu.11.1.94-102

Kaldaras, L., Wang, K. D., Nardo, J. E., Price, A., Perkins, K., Wieman, C., & Salehi, S. (2024). Employing technology-enhanced feedback and scaffolding to support the development of deep science understanding using computer simulations. *International Journal of STEM Education, 11*, Article 30. https://doi.org/10.1186/s40594-024-00490-7

Lubis, M. (2023). Digital learning media in elementary science: stimulating or demotivating? Asian Journal of Multidisciplinary Education, 1(1), 497. DOI: https://doi.org/10.61650/ajme.v1i1.497

Nakamura, D., & Sakuma, N. (2022). Effectiveness of step-by-step instruction in hypothesis setting through comparison of multiple phenomena. *Journal of Research in Science Teaching, 59*(2), 357–371. https://doi.org/10.11639/sjst.b21016

Öndeş, R. N. (2025). Effects of STEM practices on students' problem-solving skills: A meta-analysis. *International Journal of Education in Mathematics, Science and Technology, 13*(2), 439–461. https://doi.org/10.46328/ijemst.4697

Papagiannis, P., & Pallaris, G. (2024). Evaluating 21st century skills development through makerspace workshops in computer science education. *arXiv*. https://doi.org/10.48550/arxiv.2411.05012

Pokhilenko, I., Gutierrez-Colosia, M. R., Janssen, L. M. M., Evers, S. M. A. A., Paulus, A. T. G., Drost, R. M. W. A., Campoy-Muñoz, P., Simon, J., & Salvador-Carulla, L. (2024). Clarifying terminology and definitions in education services for mental health users: A disambiguation study. *PLoS ONE, 19*(7), e0306539. https://doi.org/10.1371/journal.pone.0306539

Prasonine, S., Müller, C., & Kim, H. (2023). Pattern recognition as a learning strategy in engineering education: Effects on students' conceptual understanding and pattern-based reasoning. *International Journal of Technology and Design Education, 33*(3), 567–585. https://doi.org/10.1177/03064190231203692

Pratiwi, R., & Doyan, A. (2024). The effect of science learning on students' critical thinking ability: A review. *International Journal of Science Education and Science, 1*(1), 1–5. https://doi.org/10.56566/ijses.v1i1.105

Putnam, R. F., & Jones, A. B. (2024). Investigating the effects of interactive science workshops on primary students' conceptual understanding and retention. *International Journal of Science and Mathematics Education, 22*(2), 1123–1141. https://doi.org/10.1007/s10763-024-10539-2 en.wikipedia.org+15

Romero, C., & Ventura, S. (2024). Educational Data Mining and Learning Analytics: An Updated Survey. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*. https://doi.org/10.1002/widm.1355

Saputra, A. R., Murti, R. C., & Hastuti, W. S. (2025). The effect of web-based interactive learning media on critical thinking skills of elementary school students. *Jurnal Prima Edukasia, 13*(1), 159–168. https://doi.org/10.21831/jpe.v13i1.75228

Sayed, W. S., Noeman, A. M., Abdellatif, A., Abdelrazek, M., & Badawy, M. G. (2022). AI-based adaptive personalized content presentation and exercises navigation for an effective and engaging e-learning platform. *Multimedia Tools and Applications, 82*, 3303–3333. https://doi.org/10.1007/s11042-022-13076-8

Sinaga, Y. R. A., Herliani, Boleng, D. T., Maasawet, E. T., Akhmad, & Rambitan, V. M. M. (2024). Development of neuroscience-based biology learning media to increase learning motivation and cognitive learning outcomes of Tenggarong high school students. *Jurnal Penelitian Pendidikan IPA, 10*(6), 2916–2926. https://doi.org/10.29303/jppipa.v10i6.7314

Utaminingsih, S., Amalia, I., & Sumaji, S. (2024). Management of mathematics learning based on interactive digital worksheets to improve students' critical thinking ability. *Journal of Curriculum and Teaching, 13*(1), 159–176. https://doi.org/10.5430/jct.v13n1p159

Wang, H., & Liu, J. (2023). The impact of digital infrastructure on online education in China. *Educational Technology Research and Development, 71*(2), 89–105. https://doi.org/10.1080/10611932.2023.2213602

Wang, H.-H., Hong, Z.-R., She, H.-C., Smith, T. J., Fielding, J., & Lin, H.-S. (2022). The role of structured inquiry, open inquiry, and epistemological beliefs in developing secondary students' scientific and mathematical literacies. *International Journal of STEM Education, 9*(1), 14. https://doi.org/10.1186/s40594-022-00329-z

Wood, M. (2023). Science communication as interdisciplinary training. *Journal of Science Communication, 22*(06), Y01. https://doi.org/10.22323/2.22060401