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VALIDITY OF AN INTERACTIVE E-WORKSHEET BASED ON GUIDED INQUIRY ON ENVIRONMENTAL POLLUTION MATERIAL TO TRAIN SCIENCE PROCESS OF GRADE 10 SENIOR HIGH SCHOOL STUDENTS

Validitas E-LKPD Interaktif Pencemaran Lingkungan Berbasis Inkuiri Terbimbing untuk Melatihkan Keterampilan Proses Sains Kelas X SMA

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Abstract

Science process skills are among the essential competencies that students must master in the 21st century. However, the level of science process skills among students in Indonesia remains relatively low and has not been optimally developed in classroom learning activities. The development of interactive electronic student worksheets (E-LKPD) represents a strategic approach to enhancing student's science process skills. This study aims to develop a guided inquiry-based interactive E-LKPD on environmental pollution to train student's science process skills and to evaluate its feasibility based on its validity. The developed E-LKPD offers several innovative features, including automatic time tracking, integration within a single website without the need to switch between pages, automatic feedback for each question and overall performance, as well as offline accessibility. This study employed the 4D development model (Define, Design, Develop, and Disseminate). The feasibility of the E-LKPD was evaluated by a content expert, an education expert, and a high school biology teacher. The validation process evaluated three dimensions: presentation, content, and language, using a 4-point Likert scale ranging from 1 (poor) to 4 (excellent). The validity data were analyzed statistically by calculating the average score. The results showed that the E-LKPD obtained a presentation validity score of 98.33%, a content validity score of 100%, and a language validity score of 98.33%. With a cumulative score of 98.89%, the E-LKPD was categorized as highly valid. The results indicate that the guided inquiry-based interactive E-LKPD on environmental pollution is suitable for classroom implementation to train student's science process skills.
Keywords: Validity, Interactive E-Worksheet, Environmental Pollution, Guided Inquiry, Science Process Skills.

Abstrak

Keterampilan proses sains merupakan salah satu kompetensi esensial abad ke-21 yang perlu dikuasai oleh peserta didik. Namun, keterampilan ini masih tergolong rendah di kalangan peserta didik Indonesia dan belum dilatihkan secara optimal dalam proses pembelajaran. Upaya melatihkan keterampilan proses sains dapat dilakukan dengan pengembangan E-LKPD interaktif sebagai bahan ajar peserta didik. Penelitian ini bertujuan menghasilkan E-LKPD interaktif materi pencemaran lingkungan berbasis inkuiri terbimbing untuk melatihkan keterampilan proses sains peserta didik yang layak berdasarkan validitas. E-LKPD interaktif yang dikembangkan menghadirkan sejumlah keunggulan inovatif, yaitu: merekam waktu pengerjaan secara otomatis, terintegrasi dalam satu situs website tanpa perlu berpindah ke laman lain, dilengkapi dengan umpan balik otomatis pada tiap soal dan umpan balik keseluruhan, dapat diunduh dan dikerjakan secara offline. Penelitian ini menggunakan model pengembangan 4D (Define, Design, Development dan Disseminate). Kelayakan E-LKPD interaktif diperoleh dari dosen ahli materi, dosen ahli pendidikan, dan guru biologi SMA, Penilaian kelayakan meliputi telaah dan penilaian validitas menggunakan instrumen validasi yang mencakup aspek penyajian, isi dan kebahasaan dengan penilaian skala Likert 4 poin, 1-4 (kurang baik-sangat baik). Data validitas dianalisis secara statistik melalui perhitungan skor rata-rata. Hasil penelitian menghasilkan bahan ajar E-LKPD interaktif dengan validitas penyajian E-LKPD memperoleh skor sebesar 98,33%, validitas isi sebesar 100% dan validitas kebahasaan sebesar 98,33%. Secara keseluruhan, skor validitas berdasarkan ketiga aspek memperoleh skor sebesar 98,89% dengan kategori sangat valid. Berdasarkan hasil penelitian dapat disimpulkan

bahwa E-LKPD interaktif materi pencemaran lingkungan berbasis inkuiri terbimbing untuk melatihkan keterampilan proses sains peserta didik layak diterapkan ditinjau dari validitas.
Kata Kunci: *Validitas, E-LKPD Interaktif, Pencemaran Lingkungan, Inkuiri Terbimbing, Keterampilan Proses Sains.*

INTRODUCTION

The 21st-century competencies are essential in addressing the rapid development of technology and global changes, where students are required to master knowledge and develop skills such as critical thinking, collaboration, communication, and creativity. According to the Ministry of Education, Culture, Research, and Technology (Kemendikbud Ristek, 2022), the demands of 21st-century competencies, commonly referred to as the 4Cs include creativity, critical thinking, communication, and collaboration (Abdillah & Hamimi, 2021). Education in this era must prepare students with the essential competencies to innovate, work collaboratively, and apply technology in solving social and environmental challenges. These competencies are vital for students to survive and compete in a technology-driven era (Azahra & Fitrihidajati, 2023).

There are various ways to foster these 4C skills, one of which is by training students in science process skills. According to Mahmudah et al. (2019), science process skills emphasize a balanced learning experience between theory and practice to achieve success. When students master science process skills, it impacts their conceptual and theoretical development, accompanied by the enhancement of attitudes and personal qualities. In essence, science process skills become embedded in long-term memory and foster both behavioral and cognitive competencies (Suja, 2020).

Based on a national survey conducted by the Ministry of Education, Culture, Research, and Technology in 2023, only about 30% of senior high school students demonstrated competency in independently formulating hypotheses, designing experiments, and analyzing data. This data indicates the low level of science process skills among students in Indonesia. According to Suja (2020), several factors contribute to the low achievement of student's science process skills, including: (1) many teachers feel dissatisfied if they do not deliver science content through traditional lectures; (2) difficulties in shifting student's learning habits from passive reception to active engagement and challenge-seeking; and (3) class sizes that exceed teachers' capacity, making it difficult to implement science learning as an active process.

The low level of science process skill achievement among students highlights a gap between the demands of 21st-century education and the actual skills possessed by students. This gap may arise from the current learning approaches, which have not been optimal in fostering science process skills. The instructional model that has proven effective in enhancing these skills is the guided inquiry-based learning model. Guided inquiry is a structured sequence of learning stages that encourages students to engage in systematic, in-depth, and analytical investigation, ultimately enabling them to construct knowledge independently (Hidayat et al., 2023). Research by Rahman (2022) found that the application of guided inquiry in instructional practice significantly improves student's ability to design investigations, identify variables, conduct experiments, and draw conclusions.

Optimal instructional outcomes can only be achieved when an effective learning model is accompanied by well-designed and appropriate teaching materials. One of the instructional resources that can be utilized is the student worksheet (LKPD). According to Ayuningtyas et al. (2015), LKPD is a learning resource structured in the form of task sheets that serve as a guide for activities involving problem-solving or investigation. In response to the demands of the society 5.0 era, which emphasizes the integration of technology, conventional LKPDs have evolved into electronic student worksheets, commonly referred to as E-LKPDs (Hidayati & Rachmadiarti, 2024).

Electronic Student Worksheets (E-LKPDs) have the capacity to encourage students to engage with learning materials both independently and collaboratively (Astuti et al., 2018). According to Susanti et al. (2024), the use of digital formats in E-LKPDs enables the integration of multimedia components such as videos, animations, simulations, quizzes, and discussion forums. E-LKPDs also provide space for students to develop their thinking skills, such as seeking information, hypothesizing, and reasoning—skills that are essential in solving problems and are enhanced through the many interactive features available. Instructional resources equipped with interactive features assist educators in delivering material more effectively and help students become more engaged with the content, thereby improving the quality of

classroom instruction and stimulating higher-order thinking skills (Supriadi, 2017).

The advanced features of E-LKPDs allow developers to create worksheets that are integrated with virtual laboratories. As a result, the use of E-LKPDs can serve as an alternative for schools with limited laboratory facilities to provide students with practical experiences aimed at developing science process skills. Interactive elements can also be incorporated into E-LKPDs in the form of two-way communication between teachers and students, as well as among students themselves. Another advantage of the interactive E-LKPD selected in this study is its ability to display student scores and provide real-time feedback. This is in line with Wahyuni et al. (2024), who stated that E-LKPDs generally offer the benefit of delivering automatic feedback to each student, which expedites the evaluation process and enhances conceptual understanding.

The interactive component of E-LKPDs plays a vital role in creating meaningful learning experiences and encouraging active student engagement. Conceptually, interactivity, according to Ali et al. (2024), can be defined as a characteristic or feature of instructional materials that enables two-way interaction between students and teachers, content, or other learning resources to increase engagement, learning control, and the overall effectiveness of the instructional process. Research by Ratnawati (2021) supports the notion that interactive learning media can improve student's focus and interest, thereby positively affecting learning outcomes. Therefore, integrating interactive components into E-LKPDs is a key strategy in the development of innovative teaching materials to support meaningful and effective biology learning, particularly for contextual topics.

One of the contextual biology topics that is direct relevance to student's daily life is environmental change. This topic is part of the Grade 10 curriculum under Phase E of the Merdeka Curriculum. Within the topic of environmental change lies a sub-topic on environmental pollution, which was selected for its direct relevance to student's daily lives, particularly in relation to environmental issues. Students are often exposed to environmental phenomena that present real-world problems requiring viable solutions. The environmental pollution topic must be taught both theoretically and practically through hands-on experiments to effectively trains student's science process skills. This view is supported by Ikhwani and Kuntjoro (2021), who stated that the environmental change topic requires students to conduct in-depth analyses of the causes and effects of environmental changes and subsequently propose experimental solutions to address the problems—making this material unsuitable for lecture-only methods. Therefore, the implementation of a guided inquiry learning model is necessary to train student's science process skills during the teaching and learning process. According to research by Budiyono and Hartini (2016), the application of guided inquiry in instruction has a significant impact on improving student's science process skills compared to conventional teaching models.

Based on the aforementioned problem, this study was conducted with the aim of developing a guided inquiry-based interactive E-Worksheet (E-LKPD) on the topic of environmental pollution that is feasible for training science process skills, as evaluated through expert validation instruments.

METHOD

This research is a descriptive study. The focus of the description is the validity of a guided inquiry-based interactive E-Worksheet (E-LKPD) on the topic of environmental pollution for training science process skills. The validity results are used to determine the feasibility of implementing the E-LKPD in classroom instruction. The interactive E-LKPD was developed using the Canva application and converted into a website format using Wizer.me. The E-LKPD was designed by integrating science process skill indicators into various interactive features. The indicators were adapted from Bryce et al. (1990), which include: identifying problems, determining variables, formulating hypotheses, designing experiments, interpreting data, and drawing conclusions.

This study employed the 4D development model (Define, Design, Develop, and Disseminate). The research was conducted in the Biology Education undergraduate program between January and May 2025. Data were obtained through a validation method involving three validators: a subject matter expert, an education expert, and a senior high school biology teacher.

The product validation was assessed using a validation sheet based on a Likert scale ranging from 1 to 4. A score of 1 indicates not valid, 2 indicates fairly valid, 3 indicates valid, and 4 indicates very valid.

The percentage obtained represents the ratio between the total score assigned by the validators and the maximum possible score. The formula to calculate the percentage is as follows:

$$Validity\ score = \frac{Score\ obtained}{Maximum\ score}\ x\ 100\% \ldots(1)$$

The average score of the validation was obtained using the formula below.

$$Average\ validity\ score\ = \frac{\Sigma\ Score\ obtained}{\Sigma\ Validator} \ldots (2)$$

The interpretation of the interactive E-LKPD validity score percentages refers to the assessment categories adapted from Riduwan (2016) (Table 1).

Table 1. Interval Categories for E-LKPD Validity Scores

Interval (%)	Categories
0 - 37	Not Valid
38 - 53	Less Valid
54 - 69	Fairly Valid
70 - 85	Valid
86 - 100	Highly Valid

Based on the criteria presented in **Table 1**, the interactive E-LKPD is considered valid if it obtains an average score above 70%.

RESULT AND DISCUSSION

The result of this study is a guided inquiry-based interactive E-Worksheet (E-LKPD) on environmental pollution, developed to train student's science process skills and deemed feasible based on its validity. The E-LKPD consists of 47 pages and can be accessed via the Wizer.me website using a smartphone, laptop, or computer connected to the internet. The E-LKPD is designed to integrate science process skill indicators, including identifying problems, determining variables, formulating hypotheses, designing experiments, interpreting data, and drawing conclusions.

The developed interactive E-LKPD is available online and can be accessed through the following link: https://app.wizer.me/learn/II5PN3.

The interface of the developed interactive E-LKPD is shown as follows.

Figure 1. Cover Page of the Interactive E-LKPD

Figure 2. Topic 1 of Interactive E-LKPD on Water Pollution

Figure 3. Topic 2 of Interactive E-LKPD on Air Pollution

The development of the interactive E-LKPD covers two main topics within the subject of environmental pollution, namely water pollution (Figure 2) and air pollution (Figure 3). Each topic includes a content explanation beginning with clearly defined learning objectives. According to Farhana (2023), learning objectives play a critical role as a guide throughout the student's learning process.

The E-LKPD consists of three main sections: introduction, content, and closing. The introduction includes the cover page, foreword, table of contents, general information about the E-LKPD, its features, instructions for use, a concept map of environmental pollution material, E-LKPD identity, learning outcomes, and a brief description of the material. The content section consists of learning objectives, material explanation, student activities, and reflection. The final section contains a glossary and a bibliography.

Furthermore, the interactive E-LKPD includes several features designed to facilitate student learning of environmental pollution content and to train science process skills. These features are categorized into two groups: main features and supporting features, as detailed in Table 2.

Table 2. Detailed Features in the Guided Inquiry-Based Interactive E-LKPD

Feature	Description	
	E-LKPD 1	E-LKPD 2
Main Features		
 *We Observe*	Contains an article about water pollution that causes mass fish deaths.	Contains an article about the rise in Earth's temperature over the past 10 years due to air pollution.
 *We Wonder*	Contains journals and videos about using moringa seeds as natural water purifiers.	Contains educational videos explaining the definition, impact, and human activities contributing to the greenhouse effect.
 *We Identify*	Contains activities that guide students to identify variables affecting water quality.	Contains activities that guide students to identify variables affecting air pollution levels.
 *We Create*	Presents an experimental activity focused on improving wastewater quality from detergents using moringa seeds.	Presents an activity where students design solutions to reduce carbon emissions.
 *We Find*	Provides activities that facilitate students in analyzing and interpreting experimental data, as well as drawing conclusions based on experiments aimed at improving detergent wastewater quality using moringa seeds and reducing carbon emissions.	
Supporting Features		
 *We Try*	Contains a virtual laboratory simulation on simple water filtration and result calculations.	Contains a virtual laboratory simulation on carbon emission analysis and calculations.
 *We Discuss*	Facilitates student discussions on *grey water* pollution and its relation to irrigation needs.	Facilitates discussions on air pollution issues occurring in Indonesia.
 *We Reflect*	Provides learning activities that encourage students to reflect on the learning process they have completed.	

The main features of the interactive E-LKPD include activities that are integrated with science process skill indicators, comprising: (1) We Observe, which presents an article for students to identify problems, aimed at training their problem-identification skills; (2) We Wonder, which includes journal articles and videos to support the development of hypothesis formulation skills; (3) We Identify, which contains activities that help students practice identifying variables; (4) We Create, which involves experiments or practicum activities designed to train students in designing investigations; and (5) We Find, which contains activities to support the development of data interpretation and conclusion-drawing skills. These features are implemented across both topics in the E-LKPD, namely: (1) water pollution and (2) air pollution. The main features are designed based on science process skill indicators and are applied through learning activities embedded in the E-LKPD (Margareta & Purnomo, 2018).

The supporting features are designed to enhance the teaching and learning process by helping students better understand the material on environmental pollution. These include: (1) We Try, which provides a virtual laboratory aligned with the topic; (2) We Discuss, which enables two-way discussions related to the material; and (3) We Reflect, which offers a reflection activity completed by students after engaging in the learning process. These supporting features are presented in the instructional materials as complementary elements to assist students in learning the subject matter (Meduri, 2022).

The development of the interactive E-LKPD in this study demonstrated its potential to foster self-regulated learning among students. According to Jaya et al. (2018), self-regulated learning is a process in which students are able to manage their own learning steps through planning, monitoring, and evaluating their learning outcomes. This aspect is integrated into the E-LKPD through systematically designed activities that offer flexibility in learning. All of the core features—We Observe, We Wonder, We Identify, We Create, and We Find—support students in actively understanding and analyzing scientific phenomena without relying entirely on the teacher. This shift encourages the transformation of the teacher's role from a source of information to a learning facilitator, which aligns with inquiry-based learning principles and the demands of 21st-century skills-oriented curricula (Azizah et al., 2025).

The supporting features, namely We Discuss and We Reflect, serve as added value in the developed interactive E-LKPD. We Discuss fosters student interaction both with peers and with the teacher, while We Reflect provides direct feedback from the teacher. This level of interactivity is in line with Ulfa (2022), who stated that interactive E-LKPDs should integrate multiple media formats and enable two-way communication between users and the content. Similarly, Wahyuni et al. (2024) emphasized that a good interactive E-LKPD should be easy to navigate and offer feedback as part of the learning evaluation process.

The We Try feature in the E-LKPD is presented as a virtual laboratory that functions as a simulated experimental medium to reinforce student's science process skills. The use of virtual laboratories has proven effective in enhancing concept mastery, learning outcomes, motivation, and higher-order thinking skills by providing an interactive and contextual learning experience (Majid et al., 2020). The interactivity offered enables students to observe phenomena, conduct experiments, and draw conclusions actively, even in the absence of physical laboratory equipment. Therefore, virtual laboratories are considered effective as alternatives or complements to conventional lab activities, especially in situations where equipment or time is limited (Latifah, 2019).

The validity of the interactive E-LKPD was assessed by three validators, consisting of a subject matter expert, an education expert, and a senior high school biology teacher. The validation focused on three aspects: presentation, content, and language. This validation process was conducted to ensure both the visual and content-related quality of the E-LKPD, thus determining its feasibility for classroom use as instructional material (Fitriasari & Yuliani, 2021). The results of the validation conducted by the experts are presented in Table 3.

Table 3. Validity Results of the Interactive E-LKPD (n=3)

No	Evaluated Aspects	Assessment			Average
		V1	V2	V3	
A. PRESENTATION					
1.	Quality of E-LKPD usage	4	4	4	4,00
2.	Cover design quality	4	4	4	4,00
3.	E-LKPD formatting	4	4	4	4,00
4.	Interactivity quality	4	4	3	3,67
5.	Systematics of E-LKPD presentation	4	4	4	4,00
Average Score for Presentation		3,93			
Score Interpretation		98,33%			
Category		Highly Valid			
B. CONTENT					
6.	Completeness of the E-LKPD	4	4	4	4,00
7.	Alignment of activities with learning objectives	4	4	4	4,00
8.	Alignment of the E-LKPD with the Guided Inquiry model	4	4	4	4,00
9.	Alignment of the E-LKPD with science process skills indicators	4	4	4	4,00
Average Score for Content		4,00			
Score Interpretation		100%			
Category		Highly Valid			
C. LANGUAGE					
10.	Language usage	3,75	4	4	3,93
Average Score for Language		3,93			
Score Interpretation		98,33%			
Category		Highly Valid			
Total Score		3,96			
Score Interpretation		98,89%			
Category		Highly Valid			

Notes:
V1 (Validator 1): Subject matter expert
V2 (Validator 2): Education expert
V3 (Validator 3): Senior high school biology teacher

Based on Table 3, the presentation validity of the E-LKPD received a score of 98.33%, content validity reached 100%, and language validity scored 98.33%. Overall, the developed E-LKPD obtained a total score of 3.96, equivalent to a validity level of 98.89%, which falls under the “very valid” category (Riduwan, 2013). These results indicate that the E-LKPD is feasible for use in classroom learning. An E-LKPD is considered valid

when its content and construct align with essential criteria, including conformity with the current curriculum, alignment between the content and formulated indicators as well as the material being taught, the use of communicative language, and an engaging design that supports increased student motivation during the learning process (Junita & Yuliani, 2022).

The first aspect evaluated in the validation of the interactive E-LKPD was the presentation aspect. Based on Table 3, the average score for this aspect was 3.93, with a validity percentage of 98.33%, which falls into the "very valid" category. This result indicates that the developed interactive E-LKPD meets the criteria for presentation components. It demonstrates that the E-LKPD has good operational quality. This aligns with the view of Fauziah and Sulisworo (2022), who stated that the easier it is to operate a teaching material, the easier it is for students to understand the content and achieve learning objectives. Pratiwi and Widyaningrum (2021) further added that high-quality instructional materials in terms of presentation can enhance student's learning motivation. The lowest score within the presentation aspect was found in the item regarding feedback at the end of the E-LKPD activity. Ideally, this interactive component should be explicitly mentioned within the E-LKPD so that users are aware of this feature or advantage.

The next aspect evaluated was content, which included the alignment of activities with learning objectives, completeness of the E-LKPD, compatibility with the guided inquiry model, and alignment with science process skill indicators. The average score for the content aspect was 4.00, with a validity percentage of 100%, placing it in the “very valid” category. This indicates that the developed interactive E-LKPD contains all essential components, such as learning outcomes, learning objectives, table of contents, user guidelines, glossary, and bibliography. The completeness of these supporting components facilitates students in accessing the instructional materials (Trisnawati et al., 2023). The content components assessed included subject matter, instructional phases, and student activities, all of which were aligned with the syntax of the guided inquiry model to train science process skills. All content components received a "very valid" rating from the validators, affirming that the interactive E-LKPD is feasible for classroom use. This finding is in line with Suja (2020), who emphasized that high-quality teaching materials must demonstrate alignment between the competencies to be achieved, the depth of the content, and the student's ability levels. The content validity further confirms that the E-LKPD is not only pedagogically sound but also integrates relevant and scientifically grounded biology content.

The final aspect evaluated was language use, which received an average score of 3.93 with a validity interpretation of 98.33%, categorized as “very valid.” The language assessment criteria included the use of proper and correct Indonesian, the use of simple and easily understandable language, and the clarity of instructional sentences—all of which received a perfect score of 4 from all three validators. This was demonstrated by the learning activities in the interactive E-LKPD, which were written concisely yet remained easy for students to understand due to their sequential structure and alignment with the cognitive stage of students in Phase E. This finding aligns with the statement by Itaunada & Rachmadiarti (2023), who emphasized that language use should be adjusted to the student's level of thinking to facilitate their understanding of the learning material. The lowest score within this aspect was found in the criterion related to the accurate use of foreign words and scientific terminology. This was due to some scientific names or foreign terms that were not italicized. This observation is consistent with the Indonesian Language Spelling Guidelines (PUEBI), which state that expressions or terms in foreign languages must be written in italics (Kemendikbud, 2016).

Based on the validation results of the presentation, content, and language aspects, the overall validity score was 98.89%, which falls into the “very valid” category. This indicates that the interactive E-LKPD is feasible for use in the learning process. According to the National Education Standards Agency (Badan Standar Nasional Pendidikan, 2017), the validity criteria for teaching materials include the feasibility of presentation, content, and language, which serve as the basis for determining whether instructional materials are suitable for classroom implementation. Teaching materials must undergo validation to ensure their content aligns with the intended learning outcomes (Rizanti & Jufri, 2023).

CLOSING

Conclusion

This study resulted in the development of a guided inquiry-based interactive electronic student worksheet (E-LKPD) on the topic of environmental pollution to train student's science process skills. The E-LKPD

includes integrated features such as *We Observe*, *We Wonder*, *We Identify*, *We Create*, and *We Find*. The E-LKPD meets the feasibility criteria based on a total validity score of 98.89% across the aspects of presentation, content, and language, categorized as "very valid." These results indicate that the guided inquiry-based interactive E-LKPD is feasible for use in classroom learning.

Suggestion

The researcher recommends that future studies explore the development of interactive E-LKPDs using more advanced or premium-level web platforms to enhance the visual design and overall user interface. Additionally, further research is needed to investigate the potential of interactive E-LKPDs in supporting other 21st-century education skills beyond science process skills, such as digital literacy, scientific literacy, critical thinking, collaborative working skills, and other related competencies.

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