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Development of an Environment-Based Electronic Worksheet for Chemical Equilibrium Practicum

Selviana Putri[1], Fitriani[2*], Dini Hadiarti[3]
[1,2,3]Chemistry Education Study Program, Faculty of Teacher Training and Education,
Universitas Muhammadiyah Pontianak, Indonesia

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ABSTRACT

Purpose: This research aims to develop an environmentally based practicum E-LKPD (electronic student worksheet) on Chemical Equilibrium material to address laboratory facility limitations and produce a valid, practical product with potential to improve students' conceptual understanding. **Methods:** This study used the Research and Development (R&D) method with a 3D model (Define, Design, Develop) modified from the 4D model. Subjects were 11th-grade high school students, involving a small-scale trial (9 students) and a large-scale trial (27 students) selected via purposive sampling. Data were collected through expert validation sheets, student response questionnaires, and pretest-posttest questions, then analyzed using validity and practicality percentages and Normalized Gain (N-gain). **Findings:** The E-LKPD was rated very valid by media experts (95.83%) and material experts (94.44%), and very practical based on student responses (86.36% small-scale; 87.04% large-scale). Average N-gain of 0.90 (small-scale) and 0.92 (large-scale), both in the high category, indicated the E-LKPD's potential to improve conceptual understanding. **Research Limitations:** This research was conducted in only one class at one school without a comparison group, so generalizability remains limited and further research in a broader context is needed. **Research Implications**: This E-LKPD can serve as an economical, applicable, and environmentally friendly alternative teaching material for chemistry teachers, particularly in schools with limited laboratory facilities, enabling more contextual and interactive chemical equilibrium learning. **Originality**: This research develops an environment-based practicum E-LKPD integrating local environmental potential with interactive digital features for chemical equilibrium learning, an approach still relatively rare in previous studies.

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INTRODUCTION

Chemistry education in Indonesia currently faces significant challenges in creating meaningful and contextual learning. Chemistry, as the study of matter, its structure, properties, and changes, requires methods that emphasize not only theory but also practical experiences connected to everyday life (Pratiwi & Wiyarsi, 2025). However, at the Senior High School (SMA) level, chemistry is often considered difficult and abstract, so it is less popular with students (Basyiroh & Mulyani, 2022; Priliyanti et al., 2021).

Chemical equilibrium is considered one of the most challenging topics for students because it involves highly abstract concepts, such as the nature of reversible reactions, equilibrium shifts, and complex equilibrium constant calculations. These difficulties often lead to misconceptions, as revealed in research (Permatasari et al., 2022). Students struggle to understand the dynamics of equilibrium systems and the application of Le Chatelier's principle to real-world phenomena. To minimize these misconceptions, practicums are vital because they provide direct sensory experiences that concretely reinforce abstract theories. However, the reality in the field shows that practicums are often neglected due to classic constraints such as limited laboratory equipment and materials, as well as the limited availability of supporting teaching materials.

This gap is clearly found at SMA Negeri 2 Sungai Raya, Kubu Raya Regency, West Kalimantan. As a school that represents the characteristics of schools with limited infrastructure, chemistry learning at SMAN 2 Sungai Raya tends to be theoretical. Based on observations and interviews with chemistry teachers, practical exercises are rarely conducted, so that students only memorize formulas without understanding the mechanisms of chemical systems. This finding is reinforced by interviews with students in grade XI B who expressed difficulty imagining the phenomenon of equilibrium shifts and hoped for practical exercises using simple materials that are easily found in the surrounding environment.

As a solution to limited facilities, environment-based learning offers a practical and economical approach. By utilizing natural materials such as food coloring and water at different temperatures instead of synthetic chemicals, the concept of equilibrium can be demonstrated safely and concretely. This approach not only addresses logistical constraints but also integrates the principles of Green Chemistry to foster environmental awareness (Disa et al., 2024; Koulougliotis et al., 2021; Tukan et al., 2020). The effectiveness of this approach is supported by findings (Koulougliotis et al., 2021) that reported that green chemistry-based context projects strengthened secondary school students' awareness of green chemistry principles and their argumentation skills.

In line with the digitalization of education, these practical teaching materials need to be packaged in the form of Electronic Student Worksheets (E-LKPD). The use of multimedia-based E-LKPD (video, animation, and interactive features) has been proven effective in improving the quality of learning. Previous research has shown that the use of E-LKPD on materials with abstract and procedural characteristics similar to chemical equilibrium, such as Reaction Rates and Electrolyte Solutions, can significantly improve students' understanding of concepts and science process skills (Hidayati Azkiya et al., 2022; Rahmawati & Agustini, 2023). E-LKPD provides flexible access via smartphone, which has now become an inseparable part of the daily lives of students at SMAN 2 Sungai Raya.

Furthermore, to achieve deep learning, e-LKPD needs to be designed to accommodate the diversity of student learning styles, including visual, auditory, and kinesthetic. The presentation of auditory-visual video tutorials and step-by-step guides for environment-based practicals involving hands-on (kinesthetic) activities enables each student to process information according to their learning preferences. Integrating learning styles into digital learning materials has been shown to increase cognitive engagement and conceptual understanding, so that learning is not only oriented towards mastering facts but also encourages students to construct meaning from the chemical phenomena being studied (Zahra & Annur, 2025).

Several studies have developed E-LKPD, but there are still gaps. Putri & Arianingrum, (2024) developed a PBL-based E-LKPD for Chemical Equilibrium but has not integrated environmental-based practicums. Yuniar et al., (2019) developed green chemistry lab instructions, but not yet in an interactive digital format. Currently, there is no e-LKPD lab worksheet that specifically integrates local environmental potential with interactive features that support student learning styles in Chemical Equilibrium.

Based on the analysis of the problems and research gaps, this research focuses on the development of digital learning tools in the form of E-LKPD that integrates environmental-based practicums in the Chemical Equilibrium material. This effort is expected to provide a real contribution in the form of alternative teaching materials that are economical, applicable, and environmentally friendly without reducing the essence of understanding deep chemical concepts. In addition, this development is designed as a practical solution to overcome the limited laboratory facilities at SMAN 2 Sungai Raya and other schools with similar conditions in Indonesia, so that chemistry learning is no longer limited to theoretical memorization, but becomes a contextual and inclusive learning experience for all students.

Formulation of the problem

The problem formulation in this research is as follows:

1. How valid is the E-LKPD for environmental-based practicals on chemical equilibrium material?
2. What is the practicality level of the E-LKPD for environmental-based chemistry practicums on chemical equilibrium material?
3. How effective is the development result of environmental-based E-LKPD practicum on chemical equilibrium material as teaching material at SMAN 2 Sungai Raya?

Research purposes

The objectives of this research are as follows:

1. Analyzing the level of validity of environmental-based practical E-LKPD on chemical equilibrium material.
2. Analyzing the level of practicality of environmental-based E-LKPD practicums on chemical equilibrium material.
3. Analyzing the Effectiveness of the Results of Environmental-Based E-LKPD Practicals on Chemical Equilibrium Material as Teaching Material at SMAN 2 Sungai Raya

METHOD

The research method used is Research and Development (R&D) with a 3D model modified from a 4D model (Thiagarajan, S., Semmel, DS, & Semmel, MI, 1974). includes the Define, Design, and Develop stages without the Disseminate stage (Febrianto et al., 2025).

Population and Sample

The research population was all students of class XI B of SMAN 2 Sungai Raya in the 2025/2026 academic year. The research used two trial stages: (1) a small-scale trial with 9 students of class XI B who were selected using purposive sampling based on their ability level (3 high, 3 medium, 3 low) (Sugiyono, 2019); and (2) a large-scale trial with 27 class XI B students who did not participate in the small trial.

Research Procedures

The Define stage aims to establish learning requirements through five steps: front-end analysis, learner analysis, task analysis, concept analysis, and formulation of learning objectives. The Design stage includes test development (criterion-test construction), media selection, format selection, and initial design of the E-LKPD. The Develop stage includes expert validation, limited trials, product revision, large-group trials, and final revision.

Data collection technique

Data collection was conducted through observation, interviews, and questionnaires. Interviews were conducted at the pre-research stage as part of the needs analysis. The questionnaires consisted of two types: (1) E-LKPD validation sheets by material experts and media experts using a 4-point Likert scale (SS, S, TS, STS); and (2) student response questionnaires that measured the practicality of E-LKPD from the aspects of appearance, ease of use, materials, environment-based approaches, and benefits of E-LKPD.

Data Analysis Techniques

Validity analysis is carried out based on the assessment of material experts and media experts, calculated using the formula:

$$\text{Validity Value} = \frac{Jumlah\ skor\ yang\ diperoleh}{Skor\ maksimal} x 100\%$$

The average score obtained was then confirmed against the established assessment criteria, which were based on expert opinion as seen in Table 1.

Table 1. Validation Assessment Criteria

Percentage	Criteria
81% - 100%	Very Valid
61% - 80%	Valid
41% - 60%	Quite Valid
21% - 40%	Less Valid
0% - 20%	Invalid

Source: (Azkiyah et al., 2022)

Practicality analysis was carried out based on the results of the student response questionnaire and calculated using the percentage of student responses with the formula:

$$\text{Percentage} = \frac{\text{Jumlah Skor Yang Diperoleh}}{\text{Skor Maksimum}} X\ 100\%$$

The criteria for assessing practicality in accordance with this formula can be seen in Table 2 below:

Table 2. Practicality Assessment Criteria

Percentage	Criteria
0% - 20%	Impractical
21% - 40%	Less practical
41% - 60%	Quite Practical
61% - 80%	Practical
81% - 100%	Very Practical

Source: (Azkiyah et al., 2022)

Learning effectiveness is analyzed using Normalized Gain (N-gain) (Hake, 1998) with the formula:

$$Normal\ Gain = \frac{Skor\ posttest - skor\ pretest}{Skor\ ideal - skor\ pretest}$$

The results are classified based on the established criteria as shown in Table 3. This classification makes it easier for researchers to interpret the level of learning success qualitatively.

Table 3. N-gain Level Criteria

N-gain	Criteria
$g > 0.7$	Tall
$0.3 \le g \le 0.7$	Currently
$0 < g < 0.3$	Low
$g \le 0$	Fail

RESULTS

A. E-LKPD Development Process

1. Definition Stage

The needs analysis stage was conducted to identify problems, learning conditions, and student needs that became the basis for the development of Environmentally Based Practical E-LKPD on Chemical Equilibrium material. This analysis is part of the Define step in the 3D model, which includes five sub-stages: front-end analysis, student analysis, task analysis, concept analysis, and formulation of learning objectives. The analysis was conducted through direct learning observations in class XI B as well as in-depth interviews with chemistry teachers and students at SMAN 2 Sungai Raya.

The results of the front-end analysis indicate that the learning of Chemical Equilibrium at SMAN 2 Sungai Raya is still dominated by lecture methods, with the main learning resources being textbooks and PowerPoint presentations. Practical activities have never been carried out at all due to limited laboratory facilities, both in terms of equipment and available chemicals. This condition results in one-way learning and does not provide meaningful learning experiences for students. The absence of practical activities also hinders the development of science process skills that should be developed at the high school level.

The results of the student analysis revealed that grade XI B students experienced significant difficulties in understanding the concept of chemical equilibrium, particularly in the material on equilibrium shifts and the application of Le Chatelier's Principle in real contexts. Students tended to simply memorize formulas without understanding the underlying mechanisms. In addition, student motivation towards learning chemistry was relatively low due to the difficult and abstract material and its lack of connection to everyday life phenomena. On the other hand, all students already owned smartphones and were accustomed to using digital devices, so their readiness to use digital-based learning media was considered adequate. This provides a strong foundation for developing teaching materials in an interactive digital format.

Task and concept analysis was conducted to map the structure of the Chemical Equilibrium material. Based on the resulting concept map, it was determined that the E-LKPD would focus on two main practicum activities, namely: (1) The effect of temperature on equilibrium, (2) The effect of concentration (diffusion). The formulation of learning objectives was then arranged according to the concept map and competency achievement indicators that refer to the Independent Curriculum. Overall, the results of the analysis emphasized the need to develop an Environmentally Based Practical E-LKPD that can help students understand the concept of chemical equilibrium in a concrete, contextual, and accessible manner through digital devices that students already have.

2. Design Stage

In the design stage, the initial design of the Environmentally Based Chemical Equilibrium Practicum E-LKPD product was carried out, which included three main activities: developing test instruments, selecting media, and selecting the E-LKPD format. This stage aims to produce a systematic product design before entering the development and validation stages.

The test instrument is structured in the form of pretest and posttest questions based on four competency achievement indicators, including understanding the concept of chemical equilibrium, analyzing the effects of temperature and concentration on equilibrium shifts, applying Le Chatelier's principle based on practicum results, and drawing conclusions from experiments. The questions are structured in multiple-choice format to identify conceptual understanding and detect potential student misconceptions. The instrument is validated by experts before use to meet the standards of content suitability and question format suitability.

The media chosen is the Environmentally Based Practical E-LKPD, which is designed to help students understand abstract chemical concepts through simple and contextual practical activities. The selection of digital media is based on the following considerations: (1) high accessibility via smartphones that all students already have, (2) the ability to load multimedia content such as practical demonstration videos and practical guides, and (3) flexibility of use that allows students to learn anytime and anywhere. This E-LKPD is also designed to accommodate three main learning styles: visual, auditory, and kinesthetic. The E-LKPD format is presented digitally interactively with a three-part structure, namely the beginning, the main part, and the end, as shown in the following image.

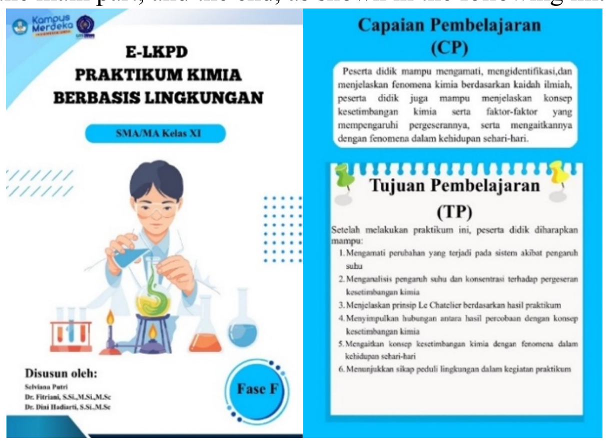


Figure 1. Initial View of the E-LKPD Practical Worksheet

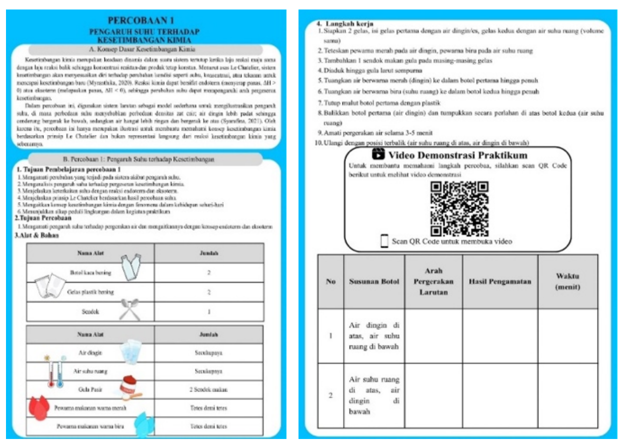


Figure 2. Display of the Contents Section of the Practical E-LKPD

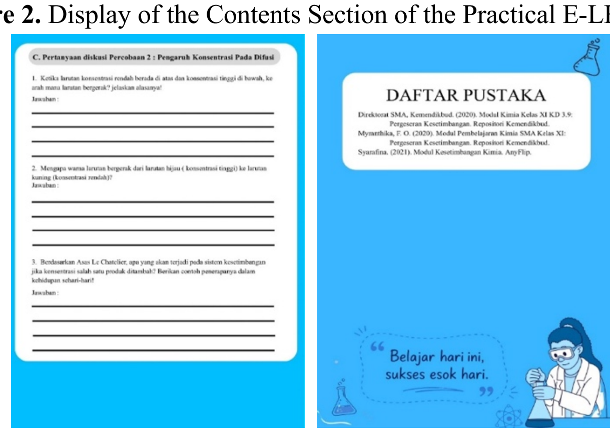


Figure 3. Final Section View of E-LKPD

3. Development Stage

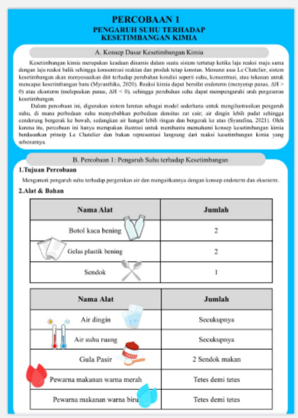
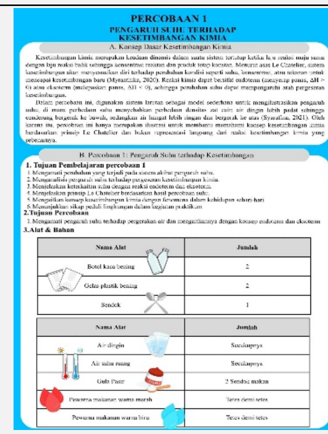
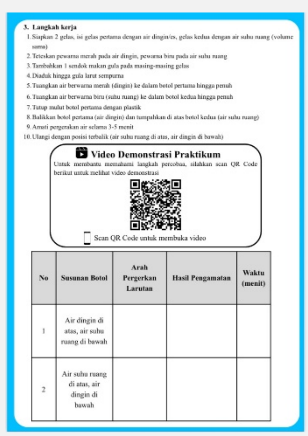
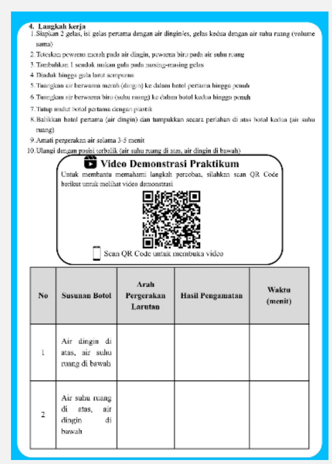
The Development phase was implemented through expert validation activities aimed at producing a valid Environmental-Based Practical Worksheet (LKPD) based on expert assessments (validators). Validity aspects were assessed based on expert assessments, while student responses were obtained through student response questionnaires. The results of the development phase are presented below.

a. Validity of E-LKPD Environmental-Based Practical Work on Chemical Equilibrium Material

The validity of the developed E-LKPD Practicum was determined through expert assessment (validators). The validation process involved six validators: three validators for the material aspect (2 lecturers and 1 teacher) and three validators for the media aspect (2 lecturers and 1 teacher). All validators were selected based on competencies relevant to their respective assessment areas. Before the product was declared final, revisions were made based on validator input at each assessment cycle. The results of the validator assessments were used to determine the level of validity of the developed E-LKPD.

Before the final assessment results, which were categorized as "Very Valid" across all aspects, were obtained, the E-LKPD was first revised based on suggestions and input from each validator. The suggested improvements and the results of the revisions are presented in the following table.

Table 4. Suggestions and revision results from the Validator

Comments and suggestions	Repair	
	Before	After
"Integrating learning objectives into the experimental section so that their achievement can be assessed directly by the teacher"		
"Improved the table writing format to align left and right."		

After revisions based on these suggestions, the E-LKPD was reassessed by the validator, resulting in a final result of "Very Valid" across all assessment aspects. The final validation results for each aspect are presented in the following table.

Table 5. Expert Assessment of E-LKPD Media Practicum

Indicator	Media expert 1	Media expert 2	Media expert 3	Average (%)	Criteria
Learning media design	100%	100%	100%	100%	Very Valid
Benefits of media	100%	87.50%	100%	95.83%	Very Valid
Media display and illustration	100%	75.00%	87.50%	87.50%	Very Valid
Media color and writing composition	100%	100%	100%	100%	Very Valid
Clear and effective media information	100%	100%	100%	100%	Very Valid
Overall average	**100%**	**90.63%**	**96.88%**	**95.83%**	**Very Valid**

Table 6. Expert Assessment of E-LKPD Practical Material

Indicator	Media expert 1	Media expert 2	Media expert 3	Average (%)	Criteria
Suitability and scope of material with CP and ATP	100%	100%	87.50%	95.83%	Very Valid
Variations in questions in providing stimulus	75.00%	100%	100%	91.67%	Very Valid
Suitability of material to students' needs	100%	100%	100%	100%	Very Valid
Arrange the material in a coherent and systematic manner	100%	100%	100%	100%	Very Valid
The appearance is appropriate to the topic of the material and is interesting	100%	100%	83.33%	94.44%	Very Valid
The suitability of the material can be accounted for	100%	75.00%	75.00%	83.33%	Very Valid
Overall average	**97.22%**	**97.22%**	**88.89%**	**94.44%**	**Very Valid**

Overall, the validation results from both media experts and material experts show that the Environmentally Based Practical E-LKPD on Chemical Equilibrium Material that was developed is in the "Very Valid" category for all assessment indicators, so it is worthy of being tested in the next stage.

b. Student Responses to the Environmentally Based Practical E-LKPD on Chemical Equilibrium Material

Student response data collection was conducted in two trial stages, namely a small-scale trial and a large-scale trial. Student responses to the E-LKPD were measured using a Likert-scale questionnaire consisting of 11 statements covering five assessment aspects: (1) E-LKPD display, (2) ease of use, (3) learning materials, (4) environment-based approach, and (5) benefits of the E-LKPD. In the small-scale trial, 9 students selected purposively (representing high, medium, and low abilities) were asked to use the E-LKPD independently and complete a student response questionnaire. Input from the small-scale trial was used as material for product revision before a large-scale trial involving 27 students of class XI B who were not involved in the small-scale trial. In this stage, students used the E-LKPD for one full learning session that included environment-based practical activities, filling out discussion sheets, and completing evaluations. The results of student responses in both trial stages are presented in the following table.

Table 7. Results of Student Responses to E-LKPD

Nu.	Trials	Number of Students	Percentage (%)	Criteria
1	Small Scale Trial	9	86.36	Very Practical
2	Large-Scale Trial	27	87.04	Very Practical

c. Effectiveness of Environmentally Based E-LKPD Practical Worksheets on Chemical Equilibrium Material

The effectiveness of E-LKPD was measured using the Normalized Gain (N-gain) calculation based on a comparison of students' pre-test and post-test results. The N-gain value was calculated for each student and then averaged for each trial group. The results of the N-gain calculation for both trial stages are presented in Table 7 below.

Table 8. N-gain Calculation Results

Group	N	Min	Max	Average N-gain	Criteria
Small Scale Trial	9	0.33	1.00	0.90	Tall
Large-Scale Trial	27	0.50	1.00	0.92	Tall

DISCUSSION

The results of the study indicate that the developed Environmentally Based Practical E-LKPD meets the three criteria for product quality development, namely validity, practicality, and effectiveness. From the validity aspect, the assessment of media experts produced an average of 95.83% and the assessment of material experts produced an average of 94.44%, both of which are in the very valid category. The high level of validity in the media aspect indicates that the display design and quality of the practical demonstration video in the E-LKPD are considered good by the validators, while the high validity in the material aspect indicates that the chemical equilibrium content presented is considered scientifically accurate and in accordance with the applicable curriculum from the perspective of the validators involved. The very valid category was obtained after the E-LKPD was revised based on validator input, including the integration of learning objectives into the experiment section so that their achievement can be directly assessed by teachers, and improvements to the table writing format to align left and right to improve the readability of the E-LKPD. The insertion of learning objectives in the experiment section is in line with the views of (Salsabilla & Jannah, 2023) that operational verbs in learning objectives need to be realized in the form of real, observable behavior or work results. The results of this study are in line with research (Disa et al., 2024) which developed a chemistry practical module based on green chemistry on chemical equilibrium material and obtained a validity index of 0.77 (valid), as well as research (Tukan et al., 2020) which developed an environmental-based practical worksheet on reaction rate material with an average validity of 84% (very reasonable). In addition, the research (Maullidyawati et al., 2022) obtained a validity of 93% on the flipped classroom inquiry-based E-LKPD, while (Fitriyah & Ghofur, 2022) reported that the Android-based E-LKPD using the Problem Based Learning model was categorized as highly valid by experts.

These results indicate that the development of interactive digital teaching materials for chemistry learning has the potential to produce products suitable for use in the learning process. However, comparisons of validity percentages between studies need to be interpreted carefully because each study used different validation instruments, number of validators, product characteristics, and development contexts. Differences in assessment scales, indicators used, and composition of validators can affect the validity percentage obtained. Therefore, the high validity value in this study is more appropriately interpreted as an indicator that the E-LKPD developed has met the criteria for highly valid based on the instruments and validators used in this study, rather than as evidence that the developed product is superior to products in other studies. The added value of the digital format compared to printed LKPD lies in its ability to present multimedia content that can enrich the learning experience and help visualize abstract chemical concepts more interactively (Tazkia & Hidayah, 2023).

Based on the practicality aspect, the results of the small-scale trial (n=9) produced a response percentage of 86.36% and the large-scale trial (n=27) produced 87.04%, both of which fall into the very practical category (81%–100%). The relatively consistent percentages across both trial stages indicate that students responded positively to the use of E-LKPD in learning chemical equilibrium. The practicality of E-LKPD is supported by several characteristics of the product developed, namely the use of materials from the surrounding environment that are easy to obtain so that the practicum can be carried out simply and economically, a digital display that can be accessed via smartphone, and systematically arranged practicum instructions that make it easier for students to participate in learning activities. The environment-based approach used also allows students to connect the concept of chemical equilibrium with phenomena close to everyday life so that learning becomes more contextual. These findings are in line with research (Putri & Arianingrum, 2024) who obtained a practicality level of 88% on the Problem Based Learning-based E-LKPD for chemical equilibrium material, (Rahmawati & Agustini, 2023) which reported a practicality percentage of 83.72%–95.07% in E-LKPD oriented to science process skills, (Azkiyah et al., 2022) which states that a product is said to be practical if it can be used easily in the learning process without technical obstacles, as well as research (Yani & Yerimadesi, 2023) which reported the practicality of the inquiry-based module at 94.76% (very practical).

Similar results were also found by (Rosa et al., 2022) on the E-LKPD acid-base based on guided inquiry, which obtained a practicality level of 81% (very practical), as well as Maullidyawati et al. (2022), who obtained a practicality level of 96% on the E-LKPD based on flipped classroom inquiry. Then, (Ayunda & Azhar, 2023) reported that a structured inquiry-based chemical equilibrium worksheet (LKPD) on liveworksheets was deemed valid and capable of increasing student active engagement. However, these results indicate that interactive digital learning materials tend to elicit positive responses from students when designed according to their learning characteristics and needs. However, the results of student responses in this study need to be interpreted proportionally. Practicality data were obtained through subjective student response questionnaires, so there is still the possibility of response bias. Student assessments can be influenced by their first experience using new digital learning media or the learning situation accompanied by the teacher during the study. Therefore, the practicality results are more appropriately interpreted as an indication that E-LKPD is easy to use and accepted by students in the context of this study.

Based on the effectiveness aspect, the average N-gain in the small-scale trial was 0.90 and in the large-scale trial was 0.92, both of which are in the high category (g > 0.7) based on Hake's (1998) criteria. These results indicate an increase in students' conceptual understanding after using the Environmentally Based Practical Worksheet (LKPD) on chemical equilibrium. This improvement in learning outcomes can be attributed to the learning characteristics applied in the E-LKPD. Environmentally based practical activities provide opportunities for students to observe phenomena related to the concept of chemical equilibrium in a more concrete manner. In addition, multimedia presentations in the form of demonstration videos of practical work enable students to obtain clearer conceptual visualizations, while guiding questions, data analysis sheets, and conclusion questions compiled in the E-LKPD provide opportunities for students to actively build conceptual understanding during the learning process. These findings are in line with research (Zahra & Annur, 2025) who obtained an average N-gain of 0.80 (high category) on E-LKPD based on differentiated learning, (Maullidyawati et al., 2022) which reported an N-gain of 0.73 (high category) on the flipped classroom inquiry-based E-LKPD for chemical equilibrium material, (Adelia & Haetami, 2023) which reports the effectiveness of guided inquiry-based chemistry practicum methods in significantly improving student learning outcomes, as well as (Haris Munandar, 2022) who found an N-gain of 0.73 (high category) from the application of the guided inquiry model to chemistry material in high school.

In general, these various studies indicate that the integration of practical activities, learning multimedia, and the inquiry approach has the potential to improve students' chemistry learning outcomes. It should be noted that the N-gain values in this study (0.90 in the small-scale test and 0.92 in the large-scale test) are in the higher range compared to some comparative studies, for example the N-gain of 0.73 reported in (Maullidyawati et al., 2022) and (Haris Munandar, 2022), and 0.80 in (Zahra & Annur, 2025). This difference is likely influenced by differences in the learning approaches applied, the characteristics and difficulty level of the material, the number and characteristics of the research subjects, and the implementation conditions in each study. Therefore, the high N-gain value in this study cannot be directly interpreted as evidence of the superiority of the developed E-LKPD compared to approaches in other studies. However, interpretation of the effectiveness results needs to be done carefully. This study used a Research and Development design without involving a control group, so the improvement in pretest and posttest results cannot be entirely attributed to the use of E-LKPD. Other factors such as test repetition, teacher assistance during the learning process, student motivation, and learning conditions during the study also have the potential to influence the improvement in learning outcomes obtained. In addition, the high N-gain value obtained in this study also needs to be interpreted proportionally due to the possibility of a novelty effect or the effect of novelty of the use of digital learning media.

The use of E-LKPD Environmental-Based Practicum, which is a new learning experience for students, is thought to increase student interest, motivation, and engagement during the learning process. Thus, the high N-gain value in this study indicates the potential for increased conceptual understanding after using E-LKPD, but cannot yet be used to draw strong causal conclusions as in experimental research involving a control group. This study also has limitations because it only involved one class at SMAN 2 Sungai Raya with a relatively limited number of students. Different student characteristics, school conditions, and learning facilities in other schools may also result in different results. Therefore, the generalizability of the study results is still limited and requires further research involving a wider sample and using a more robust research design to comprehensively test the product's effectiveness. Theoretically, the results of this study support the importance of integrating environment-based practicums and interactive digital learning media in contextual chemistry learning. These findings reinforce the constructivist and experiential learning perspectives, which emphasize that understanding abstract concepts such as chemical equilibrium will be more meaningful if students are directly involved in concrete experiences and can connect observed phenomena with the theoretical concepts being learned. The combination of visual, auditory, and visual elementsand kinesthetic in E-LKPD is also in line with the principles of multimedia learning which emphasize that presenting information through various modalities can help students manage cognitive load and strengthen conceptual understanding more optimally. These findings reinforce the constructivist and experiential learning perspectives, which emphasize that understanding abstract concepts such as chemical equilibrium will be more meaningful if students are directly involved in concrete experiences and can connect observed phenomena with the theoretical concepts being studied. The combination of visual, auditory, and kinesthetic elements in the E-LKPD is also in line with the principles of multimedia learning, which emphasize that presenting information through various modalities can help students manage cognitive load and strengthen conceptual understanding more optimally. Practically, the developed E-LKPD can be an alternative teaching material for schools with limited laboratory facilities because it utilizes materials that are easily obtained from the surrounding environment and can be accessed using students' smartphones. Thus, the Environmentally Based Practical E-LKPD on Chemical Equilibrium has the potential to support chemistry learning that is more contextual, interactive, and appropriate to the learning needs in high schools.

CONCLUSION

This research successfully developed an Environmentally Based Practical E-LKPD on Chemical Equilibrium material that met the criteria of very valid based on the assessment of media experts (95.83%) and material experts (94.44%), and very practical based on student responses in small-scale trials (86.36%) and large-scale trials (87.04%). The results of the N-gain calculation in small-scale trials (0.90) and large-scale trials (0.92), which were in the high category indicated that the use of E-LKPD has the potential to help improve students' conceptual understanding in the context of this research. This research contributes to the development of chemistry education by providing an initial product in the form of an environmentally based practical E-LKPD that integrates simple practicums and interactive digital learning media as an alternative teaching material for schools with limited laboratory facilities. However, the results of this study need to be interpreted carefully because the product testing was only conducted in one class in one school with a limited number of students and without a comparison group, so the research findings cannot be generalized widely. Therefore, further research is recommended to test the product on larger and more diverse samples and integrate the Disseminate stage to obtain stronger empirical evidence regarding the potential use of E-LKPD in chemistry learning in high school.

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AUTHOR CONTRIBUTION STATEMENT

SP designed the study, collected and analyzed the data, and wrote the initial draft of the article. F and DH supervised, validated the product, and reviewed and refined the manuscript.

Selviana Putri
Chemistry Education Study Program, Faculty of Teacher Training and Education
Universitas Muhammadiyah Pontianak,
Jalan Jenderal Ahmad Yani No. 111, Bansir Darat, Kota Pontianak, Kalimantan Barat
Email: 221620006@unmuhpnk.ac.id

***Fitriani (Corresponding Author)**
Chemistry Education Study Program, Faculty of Teacher Training and Education
Universitas Muhammadiyah Pontianak,
Jalan Jenderal Ahmad Yani No. 111, Bansir Darat, Kota Pontianak, Kalimantan Barat
Email: fitriani@unmuhpnk.ac.id

Dini Hadiarti
Chemistry Education Study Program, Faculty of Teacher Training and Education
Universitas Muhammadiyah Pontianak,
Jalan Jenderal Ahmad Yani No. 111, Bansir Darat, Kota Pontianak, Kalimantan Barat
Email: dinihadiarti@unmuhpnk.ac.id