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DEVELOPMENT OF A PROBLEM-BASED LEARNING-ORIENTED INTERACTIVE E-WORKSHEET ON CHEMICAL EQUILIBRIUM TO ENHANCE STUDENTS' SCIENTIFIC LITERACY SKILLS

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ABSTRACT

Indonesian students' scientific literacy scores decreased by 13 points from PISA 2018, indicating that the scientific literacy skills of participants in Indonesia are low. One area of concern is students' understanding of chemical equilibrium, which is essential because it is a prerequisite for grasping subsequent materials. This study aims to assess the feasibility of interactive e-worksheets as a learning medium for chemical equilibrium material in terms of validity, practicality, and effectiveness. According to Thiagarajan, the research employs the 4-D research and development model, which includes Defining, Designing, Developing, and Disseminating but is limited to the development stage. A limited trial was conducted using a one-group pretest-posttest research design. Validation results show that the interactive e-worksheet is valid with a mode value of 4 in content, presentation, language, and design. The validity test results yielded a mode value 4 for both content and construct validity. The practicality test results indicated a high percentage of practicality with very practical criteria. The effectiveness test, analysed using n-gain, showed an n-gain value of 0.78 with high criteria, and the paired sample t-test results indicated a P-value of 0.000, confirming that the post-test scores were significantly higher than the pretest scores. Thus, the PBL-oriented Interactive e-worksheet can improve students' scientific literacy skills.

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INTRODUCTION

Nowadays, science and technology are developing rapidly, making literacy one of the most important educational issues of the 21st century. As a scientifically literate population, countries can make informed scientific, technological, and social policy decisions [1]. Scientific literacy can help students understand and analyse problems so that students can find solutions using their scientific knowledge [2]. Students should be able to think critically, cooperate with others, communicate their ideas clearly, and solve problems creatively in their daily life problems [1]. By having these skills, students are expected to solve daily life problems. Students can learn these skills if they are scientific-literate students [3]. Thus, good scientific literacy skills are needed. This contradicts the results of PISA in 2022;

Indonesia obtained a scientific literacy score of 383, which showed a decrease of 13 points from PISA 2018 [4]. This shows that the scientific literacy skills of students in Indonesia still need to improve, so efforts are needed to deal with this problem. One of the efforts that can be taken is to develop learning media that can train scientific literacy skills. Indonesian students' low scientific literacy skills are seen in research results in two schools in the district of Sumenep. In the first school, the average obtained in the competency domain of explaining phenomena scientifically and designing and evaluating scientific investigations was in the low category. The competency of interpreting data and scientific evidence was in the sufficient category. In the second school, the average obtained in scientific literacy competencies was included in the low category [5]. A study has been conducted on developing a flipped classroom inquiry-oriented e-worksheet on chemical equilibrium material to train scientific literacy, so it is necessary to update the e-worksheet developed, one of which is by adding features that make the e-worksheet interactive and using the PBL learning model. This can be an effort to fulfil the demands of 21st-century skills, namely information media and technology skills.

Chemistry is one part of science that is studied in senior high school. In learning chemistry, students are not only emphasised on understanding concepts but are also required to apply science concepts to solve daily life problems related to science. There is a relevance between chemistry concepts and scientific literacy, as evidenced by research showing a strong and significant positive correlation between the variables of understanding basic chemistry concepts and the variables of strengthening the results of TIMSS and PISA studies. Scientific literacy will be achieved if students connect practical knowledge to their understanding of basic science concepts [6].

Chemical equilibrium is a fundamental topic in high school chemistry that encompasses the types of reaction equilibria and the factors influencing them. A comprehensive understanding of chemical equilibrium is critical as it is a prerequisite for more advanced topics, such as acid-base reactions, salt hydrolysis, buffer solutions, solubility, and solubility product calculations [7]. Additionally, mastering chemical equilibrium concepts is essential for solving real-world problems, including the causes and prevention of dental caries. Therefore, developing innovative instructional media that facilitate students' deeper understanding of chemical equilibrium is imperative.

To achieve a profound comprehension of chemical equilibrium, implementing a student-centred learning model that promotes autonomy and provides opportunities for students to explore and construct their knowledge is essential for enhancing educational outcomes [8]. One such student-centred approach is the Problem-Based Learning (PBL) model, which engages students in a learning process that begins with real-world contextual problems, promotes active group learning, encourages the formulation of problems, identifies knowledge gaps, and involves independent study to address the identified issues [9].

Research comparing the PBL model to direct instruction has demonstrated a significant improvement in conceptual understanding among students who engaged in PBL, as opposed to those taught via traditional methods [10]. Moreover, the PBL model has been shown to enhance students' scientific literacy skills more effectively than direct instruction, as studies indicate that PBL-based classes achieve higher gains in scientific literacy [11]. This underscores the importance of incorporating PBL to foster scientific literacy among students. The efficacy of the PBL model is further supported by research findings that indicate students' critical thinking skills are markedly higher when taught using PBL compared to conventional teaching models [12]. Furthermore, PBL encourages students to actively seek solutions to the presented problems, fostering a deeper engagement with the learning content [13].

In the digital era, learning cannot solely depend on smartphones as mere sources of knowledge but must harness creativity derived from the information accessed through these devices [14]. Educators must employ diverse strategies to facilitate learning [15], including leveraging technological advancements to develop innovative learning media. One such resource is the Student Activity e-worksheet, a platform for structured learning activities to discover theories and evidence concepts and conduct investigations. Worksheets are characterised by clear workflows and explicit instructions designed to enhance thinking skills and task performance in line with targeted learning indicators [16]. This study developed an electronic version of an e-worksheet based on scientific literacy components to enhance students' scientific literacy skills.

A critical aspect of 21st-century competencies is proficiency in information, media, and technology skills. To fulfil these requirements, innovation in learning media development is essential. One such innovation is the interactive electronic worksheet, a digitally packaged student worksheet featuring various tools to support independent learning [17]. The primary distinction between traditional worksheets and e-worksheets lies in their format: while worksheets are available in print, e-worksheets are accessible electronically via PCs, smartphones, or tablets.

Given the need to further enhance students' scientific literacy, additional innovations in learning media are required. This study, titled "Development of Problem-Based Learning Oriented Interactive e-worksheet on Chemical Equilibrium Material to Improve Students' Scientific Literacy Skills," aims to develop a PBL-oriented interactive e-worksheet that is feasible and effective for teaching chemical equilibrium. The research objectives include assessing the developed e-worksheet regarding validity, practicality, and effectiveness. The hypothesis of this study posits that the developed PBL-oriented interactive e-worksheet is both feasible and capable of improving students' scientific literacy skills.

METHODS

1. Research Design

This study employs a research and development approach, specifically Thiagarajan's 4-D model development design, which comprises the stages of Define, Design, Develop, and Disseminate [18]. However, time constraints limited this research to the development stage. A limited trial was conducted using a one-group pretest-posttest design, in which pretests and posttests were administered to the same subjects. The pretest was conducted before using the interactive E-Worksheet, and the posttest was conducted after its implementation. The research design is illustrated in the following diagram.

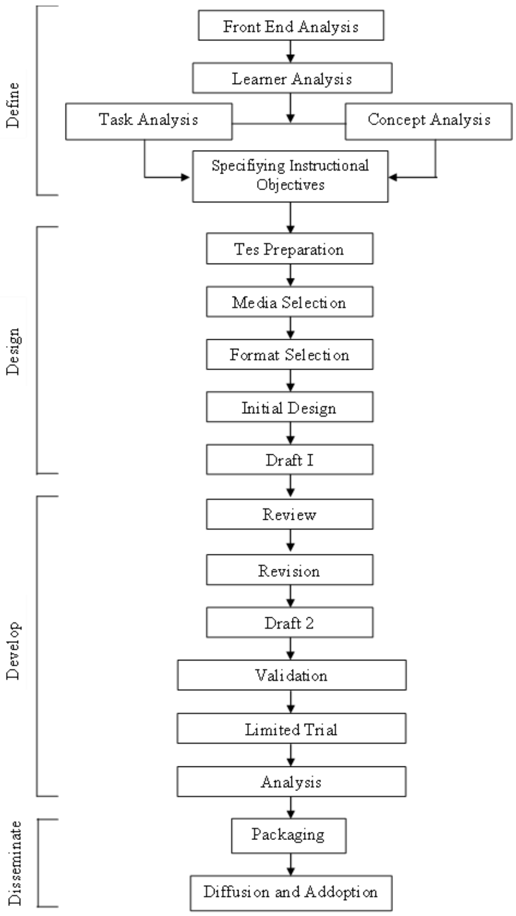

Figure 1. Research Design

2. Participants

The participants in this study were students from Eleventh Grade at a high school in Gresik District. The selected school has an A accreditation rating and follows an independent curriculum. A total of 36 students were randomly selected to participate in the study.

3. Instruments

The instruments used in this study included media validation forms, student activity observation forms, student response questionnaires, and pretest-posttest assessments of scientific literacy skills. The validation form was used to assess the validity of the developed media, encompassing criteria such as content, presentation, language, and design, and was evaluated by three expert validators. The student observation form was used to collect data on student activities during the limited trial process, with observations recorded by the observer during learning activities involving the interactive E-Worksheet.

The student response questionnaire was employed to gauge students' opinions of the PBL-oriented interactive E-worksheet as a learning medium. Students completed this questionnaire after using the developed E-Worksheet, ensuring an accurate reflection of their responses. The scientific literacy test instrument consisted of a pretest-posttest format with questions aligned to students' expected learning objectives. These questions were designed according to the scientific literacy indicators, including the context, knowledge, and competency domains. They used pretest-posttest assessments, which evaluated improvements in students' scientific literacy skills across the three domains. Experts validated all instruments used in this study before deployment in the limited trial.

4. Data Collection Methods

The data collection methods used in this study included the following:

a. Questionnaire Method

The study utilised the E-worksheet validation questionnaire and the student response questionnaire. The E-worksheet validation questionnaire was employed to gather data on the validity of the developed learning media and was administered to validators during the development stage of the research. The validation questionnaire assessed content, presentation, language, and design criteria on a 0-5 scale. The student response questionnaire was used to evaluate the practicality of the PBL-oriented interactive E-Worksheet. This questionnaire, consisting of positive and negative statements, was administered to students after using the E-Worksheet, with response options of "Yes" and "No."

b. Observation Method

Observations were conducted during the product trial to assess the practicality of the interactive E-Worksheet. Observers used the student activity observation sheet to evaluate student engagement during the limited trial phase. The observers rated student activities in each PBL phase on a 5-point Likert scale.

c. Pretest and Posttest

The scientific literacy pretest and posttest were administered to obtain quantitative data on students' scientific literacy skills, determining the effectiveness of the developed interactive E-Worksheet. The pretest was conducted before the commencement of the learning process to assess students' baseline abilities. At the same time, the posttest was administered after the learning process to measure the impact on students' scientific literacy skills following the interactive e-Worksheet. The pretest and posttest were delivered via Google Forms, comprising ten multiple-choice questions designed to align with the scientific literacy domains.

5. Data Analysis Techniques

The data analysis methods used in this study included:

a. Validity

The validity of the E-worksheet was evaluated by two chemistry lecturers and one chemistry teacher using a validation form that assessed the feasibility of content, presentation, language, and design. The validation results were analysed descriptively and quantitatively, with scores assigned based on a Likert scale ranging from 1 to 5. A score of 5 corresponds to "Very Good," 4 to "Good," 3 to "Enough," 2 to "Less," and 1 to "Very Less" [19].

The data from the assessments of each indicator were analysed using the mode value, which represents the most frequently occurring score among the validators. For instance, if an aspect received scores of 4, 4, and 3 from the three validators, the mode value would be 4, indicating that the aspect meets the "Good" criteria. This analysis was conducted across all assessed aspects to determine the overall validity of the interactive E-Worksheet. The developed interactive E-worksheet is considered valid if the validation results achieve a mode value of

4 or higher, which aligns with the "Good" criteria [20].

b. Practicality

The practicality of the E-worksheet was assessed using a student response questionnaire that contained both positive and negative statements, with scoring based on the Guttman scale. For positive statements, a "Yes" response earned 1 point, while a "No" response earned 0 points; for negative statements, a "No" response earned 1 point, while a "Yes" response earned 0 points. The data were analysed using the following formula:

$$P = \frac{Total\ Score\ of\ Each\ Aspect}{Total\ Respondents} \times 100\% \qquad (1)$$

For instance, if 34 out of 36 students answered "Yes" to a positive statement, the calculation is as follows:

$$P = \frac{34}{36} \times 100\% = 94{,}4\%$$

The percentage results are interpreted into scores using the criteria in Table 1.

Table 1. Interpretation of Practicality Score

Percentage (%)	**Criteria**
76 - 100	Very Practical
51 - 75	Practical
26 - 50	Less Practical
0 - 25	Impractical

[21]

The product is considered practical or very practical if it meets a minimum score of ≥ 51%. Practicality data were also supported by observations of student activities conducted by observers using a 1-5 scale. Student activity data during the use of the PBL-oriented interactive E-worksheet were analysed descriptively and quantitatively using the formula:

$$P = \frac{Gain\ Score}{Maximum\ Score} \times 100\% \qquad (2)$$

The percentages are then interpreted according to Table 2.

Table 2. Interpretation of Student Activity

Percentage (%)	Criteria
0 – 20	Very Less
21 – 40	Less
41 – 60	Enough
61 – 80	Good
81 – 100	Very Good

[22]

A score of ≥ 61% indicates that the PBL-oriented interactive E-worksheet is practical or very practical and suitable for teaching and learning.

c. Effectiveness

The effectiveness of the E-worksheet was determined using the pretest and posttest results of scientific literacy skills, analysed through N-gain analysis, which measures the effectiveness of an intervention on learning outcomes [23]. The formula for N-gain is:

$$N - gain = \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score} \qquad (3)$$

For example, if a student scored 40 on the pretest and 90 on the posttest, the calculation is:

$$N - gain = \frac{90 - 40}{100 - 40} = 0{,}83$$

Table 3. Interpretation of N-Gain Score

N-gain	Criteria
N-gain ≥ 0,7	High
0,3 ≤N-gain< 0,7	Medium
N-gain< 0,3	Low

[24]

The effectiveness of the developed E-worksheet was determined using the N-gain score, where a value of 0.3 or higher signifies that the product is effective or very effective. To further assess the improvement in students' scientific literacy skills, the pretest and posttest results were analysed using the paired sample t-test, which compares measurements taken before and after the intervention on the same group of subjects [25]. The analysis was performed using the Minitab software, facilitating statistical testing to identify significant differences in scientific literacy skills pre-and post-intervention.

Before conducting the paired sample t-test, a normality test was performed using the Shapiro-Wilk method, which is appropriate for sample sizes smaller than 50. The purpose of the normality test was to confirm whether the data were normally distributed, which is a prerequisite for conducting the t-test. The normality of the data is indicated by a p-value greater than 0.05, while a p-value less than 0.05 would indicate that the data are not normally distributed [26].

The paired sample t-test was then used to compare the pretest and post-test scores. A significant p-value (less than 0.05) from this test would suggest a statistically significant improvement in scientific literacy skills after using the interactive E-Worksheet, confirming its effectiveness. Conversely, a p-value greater than 0.05 would indicate no significant difference between pretest and posttest scores, suggesting the intervention did not result in a measurable improvement.

RESULTS AND DISCUSSION

This study aims to evaluate the feasibility of a Problem-Based Learning (PBL)-oriented interactive E-worksheet focused on chemical equilibrium in enhancing students' scientific literacy skills. The feasibility of the E-worksheet is assessed based on its validity, practicality, and effectiveness. Validity encompasses content and construct validity, practicality refers to the alignment between expected outcomes and actual results, and effectiveness pertains to the extent to which the intervention achieves the desired impact [20]. This research follows the 4-D model development design as outlined by Thiagarajan, which includes the stages of Define, Design, Develop, and Disseminate.

1. Define

In the Define stage, the requirements for developing the e-worksheet were established through a series of analyses. This stage was conducted at a school in Gresik Regency and involved five critical components: front-end analysis, student analysis, task analysis, concept analysis, and learning objective analysis. The front-end analysis began with a review of relevant literature and school observations, including interviews with chemistry teachers. These interviews revealed that the most commonly used learning media were printed Learner Activity Sheets (e-worksheet), and it was noted that students exhibited low scientific literacy skills due to the lack of specific interventions aimed at improving these skills. Additionally, it was found that the school employs the Merdeka curriculum, which emphasises developing critical thinking skills to analyse scientific claims and evaluate everyday phenomena. Consequently, the developed e-worksheet was designed to present scientific phenomena related to chemical equilibrium in everyday life, encouraging students to analyse these phenomena. This approach is intended to help students apply their scientific knowledge to real-world situations and enhance their critical thinking abilities. The e-worksheet's scientific phenomena align with scientific literacy's context domain, making learning more engaging and meaningful for students. PISA 2018 defines scientific literacy as engaging with and understanding scientific issues and ideas [28].

The student analysis aimed to identify the characteristics of the students, including their academic abilities, age, cognitive development, prior experiences with chemistry, motivation towards chemistry, and existing skills. Information was gathered through interviews with chemistry teachers. The limited trial involved eleventh-grade science program students aged 16–18 at the formal operational stage of cognitive development. At this stage, students can understand abstract concepts, reasoning logically and critically, and solving problems systematically through experiments. The participants in the study had heterogeneous academic abilities and had not previously studied chemical equilibrium using the PBL-oriented interactive e-worksheet designed to improve scientific literacy skills.

Task analysis involved identifying the primary tasks students engage in during learning activities, particularly those aimed at enhancing scientific literacy skills. The tasks embedded in the e-worksheet require students to solve problems using the stages of the PBL learning model. A review of relevant literature informed this task analysis. Concept analysis focused on categorising the key concepts that students need to learn, specifically the concept of chemical equilibrium and the factors influencing shifts in chemical equilibrium. This analysis produced a concept map outlining the chemical equilibrium content students would study, and it was conducted through a literature review at Surabaya State University. Finally, the analysis of learning objectives resulted in formulating learning outcomes and objectives that align with the independent curriculum based on the findings from task and concept analyses. The primary learning objectives set for the e-worksheet are that students should be able to analyse and explain the factors affecting shifts in chemical equilibrium in everyday contexts and accurately interpret experimental results related to these factors.

2. Design

In the design stage, the development process begins with preparing scientific literacy tests aligned with the predetermined learning objectives. Following this, content materials for the e-worksheet, such as images, videos, and animations relevant to chemical equilibrium topics, are gathered. The design of the Problem-Based Learning (PBL)-oriented e-worksheet, aimed at enhancing scientific literacy skills, integrates three domains of scientific literacy with the five phases of the PBL model. The e-worksheet was created using the Canva platform for content design and Typeform for the electronic answer sheets.

The developed e-worksheet comprises three main sections, which influence chemical equilibrium, focusing on temperature, concentration, volume and pressure. The outcome of this design stage is referred to as Draft 1. The e-worksheet is accessible via PC, smartphone, or tablet, ensuring flexibility for student use. The following illustrates the e-worksheet cover as it appears on a smartphone.

Figure 2. Display of Interactive E-Worksheet

Key features of the interactive E-worksheet include navigational and functional tools designed to enhance user experience and facilitate learning.

Figure 3. Back to Table of Contents Feature

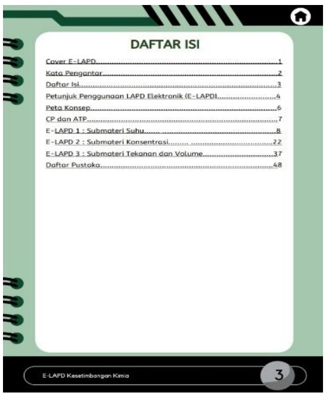

Figure 4. Table of Contents

Clicking on the icon in the right corner of the page redirects the user to the table of contents, allowing easy navigation through the e-worksheet.

Selecting an item from the table of contents directs the user to the corresponding section or page, streamlining access to specific content.

Figure 5. QR Code

This feature includes QR codes that link to supplementary readings, which aid in hypothesis formulation, data analysis, and conclusion drawing.

Figure 6. Electronic Answer Sheet

The interactive e-worksheet also includes an electronic answer sheet feature, enabling students to input their responses directly, supporting a seamless learning process.

3. Develop

The development stage involves review, validation, and limited trial processes.

The initial review was conducted by a chemistry lecturer, who provided feedback incorporated into Draft 1, resulting in the creation of Draft 2. This version was subsequently validated by two chemistry lecturers and one chemistry teacher. The validation process assessed content and construct validity, including presentation, language, and design. The validation results indicated that the e-worksheet achieved a mode score 4 across all components—content, presentation, language, and design—deeming it valid. Specifically, the content validity included assessments of the alignment of the e-worksheet material with the Core Principles (CP) and Achievement Target Points (ATP) of the Merdeka Curriculum, its appropriateness for enhancing scientific literacy skills, and its suitability for a Problem-Based Learning model. The mode score of 4 for content feasibility reflects good appropriateness. Presentation validity focused on the clarity of images and videos, while language validity evaluated the accuracy and consistency of terminology. Both aspects achieved a mode score of 4, categorised as good. The design validity examined the visual harmony between text and images within the e-worksheet, also receiving a mode score of 4, indicating good criteria. The validation results confirm that the e-worksheet is valid and suitable for educational use.

Following validation, a limited trial was conducted further to evaluate the practicality and effectiveness of the e-worksheet. This trial occurred in a school in Gresik District, involving 36 students from an eleventh-grade science program who had yet to study chemical equilibrium. The trial employed a one-group pretest-posttest design to determine the usability and impact of the e-worksheet on enhancing scientific literacy. In this context, practicality refers to the consistency between the expected and actual use of the learning media in educational settings [20]. The practicality of the e-worksheet was measured using a student response questionnaire and a student activity observation form. The questionnaire included positive and negative statements regarding various aspects of the e-worksheet, and the results are as follows: content received 85.18%, display scored 87.5%, presentation achieved 92.6%, alignment with scientific literacy competencies scored 87.22%, and student engagement in PBL reached 94.4%. Each of these percentages falls within the "very practical" range, underscoring the high practicality of the interactive e-worksheet.

The practicality of the interactive e-worksheet was further supported by observations of student activities during the learning process. Observers completed student activity observation forms at each session using the PBL-oriented interactive E-Worksheet. The form covered 15 aspects of observation aligned with the different phases of the PBL model, and the observations were conducted with 36 students divided into six groups. The results of these observations are summarised as follows: during Phase 1 (Problem Orientation), a score of 83.06% was achieved; in Phase 2 (Organizing Students), 88.89%; Phase 3 (Guiding Individual and Group Investigations) received 85.95%; Phase 4 (Developing and Presenting Work) scored 82.22%; and Phase 5 (Analyzing and Evaluating the Problem-Solving Process) achieved 87.78%. The average score across all phases was 85.58%, indicating that the E-worksheet falls within the "very practical" category for enhancing students' scientific literacy skills.

A detailed analysis of the phases revealed that in the Problem Orientation phase, students analysed problems within global, national, or personal contexts, resulting in a score of 88.33%, which was classified as very good. The Organizing Students phase, where students read content and answered relevant questions, achieved a score of 90%. The Guiding Individual and Group Investigations phase, involving experiment design, execution, and analysis, received 88.89%. In the Developing and Presenting Work phase, where students presented experiment results, data analyses, and conclusions, the score was 86.67%; this phase had the lowest percentage, attributed to some students' lack of engagement during presentations. Finally, the Analyzing and Evaluating the Results of Work phase scored the highest, with 93.33%, as students demonstrated high enthusiasm in summarising learning outcomes. These results collectively affirm the practicality and effectiveness of the PBL-oriented interactive E-worksheet in improving students' scientific literacy skills.

4. Evaluating the Effectiveness of E-Worksheet

The next stage is the effectiveness test, which assesses whether the product achieves the intended outcomes when applied in practice [20]. In this study, the goal is to enhance students' scientific literacy skills. Effectiveness was measured using a pretest-posttest assessment of scientific literacy skills consisting of 10 multiple-choice questions. Each question addresses the three domains of scientific literacy: the knowledge, context, and competency domains. The pretest was administered before using the interactive e-worksheet to assess students' initial scientific literacy abilities. At the same time, the posttest was conducted after using the developed interactive e-worksheet to evaluate the improvement in students' scientific literacy skills. Below is an example of one of the pretest and posttest questions used to assess students' scientific literacy skills.

Dikutip dari detik.com, pada 2019 sebanyak 11 orang meninggal di *Death Zone* Gunung Everest. Umumnya, kasus kematian di Gunung Everest disebabkan oleh efek *Death Zone*, baik secara langsung seperti kehilangan fungsi penting tubuh atau tidak langsung seperti ceroboh dan kelelahan karena kondisi ekstrem di sana. *Death Zone* adalah area di atas 8.000 mdpl di Gunung Everest. Di ketinggian ini, sulit untuk bernapas karena ketersediaan oksigen kian menipis, seperti dikutip dari Insider. Data sampel darah menunjukkan bahwa pendaki di *Death Zone* hanya mendapat seperempat dari total oksigen yang dibutuhkan tubuh.

Pada kasus ini, volume oksigen yang dihirup pendaki akan semakin kurang pada ketinggian tertentu. Adapun reaksi kesetimbangan dalam darah yang mengikat oksigen (O_2) sebagai berikut

$$O_2(aq) + Hb(aq) \rightleftharpoons HbO_2(aq)$$

Pernyataan yang sesuai dengan fenomena di atas adalah…..

A. Ketika pendaki mendaki semakin tinggi, tekanan udara akan semakin rendah dan volumenya semakin besar sehingga kesetimbangan bergeser ke kanan dan HbO_2 meningkat
B. Ketika pendaki mendaki semakin tinggi, tekanan udara akan semakin besar dan volumenya semakin besar sehingga kesetimbangan bergeser ke kiri dan HbO_2 menurun
C. Ketika pendaki mendaki semakin tinggi, tekanan udara akan semakin besar dan volumenya semakin kecil sehingga kesetimbangan bergeser ke kanan dan HbO_2 meningkat
D. Ketika pendaki mendaki semakin tinggi, tekanan udara akan semakin rendah dan volumenya semakin kecil sehingga kesetimbangan bergeser ke kiri dan HbO_2 menurun
E. Ketika pendaki mendaki semakin tinggi, tekanan udara akan semakin besar dan volumenya semakin besar sehingga kesetimbangan bergeser ke kanan dan HbO_2 meningkat

Figure 7. Sample of Pretest and Posttest Questions

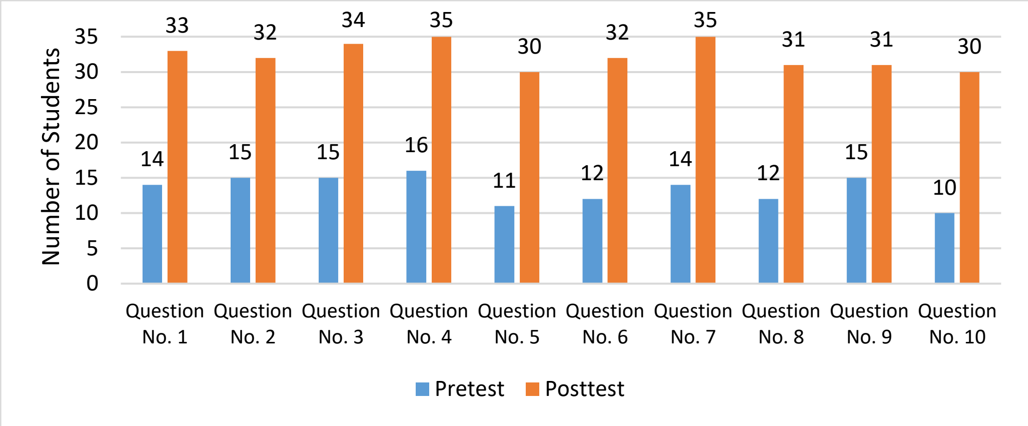

Figure 8. Improvement in The Total Number of Correct Answers on The Pretest and post-test

Based on Figure 8, it is evident that there is an increase in the number of correct answers across all questions in the posttest. The pretest and posttest question indicators are presented in Table 5. The improvement in each scientific literacy domain is shown in Figure 8.

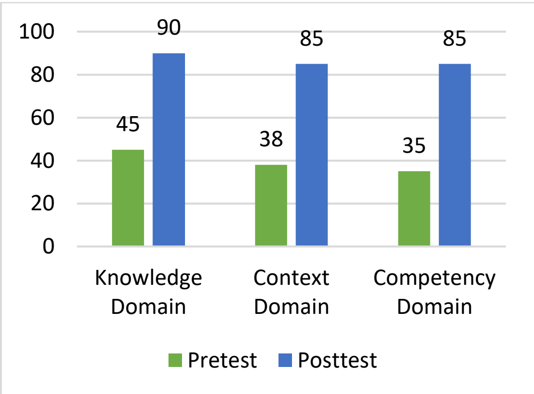

Figure 9. Improvement in Each Scientific Literacy Domain

The pretest and posttest scores were further analysed using a paired sample t-test, which is used to compare the averages of two related samples taken from the same subjects [25]. This statistical method is utilised to assess the effectiveness of the intervention by measuring the difference in means before and after treatment. The pretest and posttest scores were analysed using a normality test to examine the data distribution. The Shapiro-Wilk test was employed for normality testing because the sample size was less than 50, and the analysis was conducted using the Minitab application. The criterion for normality was a P-value greater than 0.05, which would indicate that the data are normally distributed [26]. The results of the normality test are presented below.

Table 5. Question Indicators

Question Indicators	Question Number
Presented with a phenomenon and data, students can analyse the pressure and volume factors in shifting equilibrium well.	1 and 4
Students can correctly give a statement related to the concentration factor on the equilibrium shift when presented with a phenomenon.	2, 5, 6, 7, and 8
Students can appropriately analyse the temperature factor in the equilibrium shift when presented with a phenomenon.	3, 9, and 10

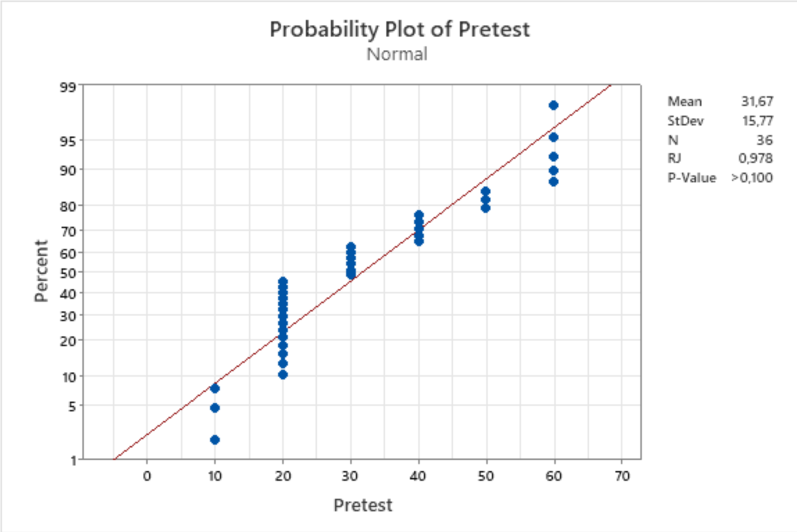

Figure 10. Result of Pretest Data Normality Test

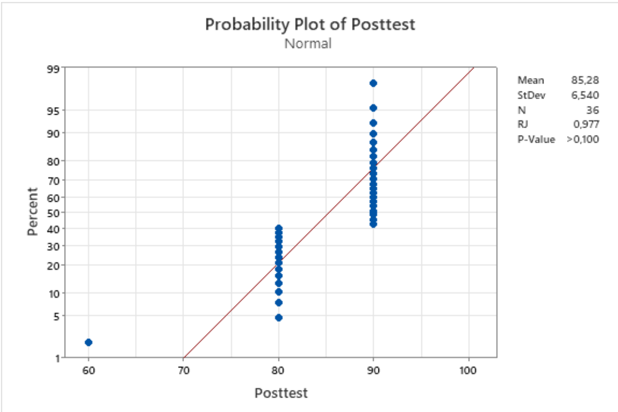

Figure 11. Result of Posttest Data Normality Test

Figures 10 and 11 show that the obtained P-value is 0.100, greater than 0.05, indicating that the pretest and posttest data are normally distributed [26]. The next step involved conducting a paired sample t-test using the Minitab application. The hypotheses tested were as follows: the null hypothesis (Ho) states that the posttest scientific literacy value after using the E-worksheet is less than or equal to the pretest value. In contrast, the alternative hypothesis (Ha) posits that the posttest scientific literacy value is greater than the pretest value. The decision rule is that if the P-value is less than 0.05, Ho is rejected, and Ha is accepted, indicating that the posttest value is significantly greater than the pretest value. Conversely, if the P-value is greater than 0.05, Ho is accepted, and Ha is rejected, suggesting that the posttest value is less than or equal to the pretest value. The E-worksheet can improve students' scientific literacy skills if the paired sample t-test results in a P-value of less than 0.05.

Table 6. Result of Paired Sample t-test

T-Value	P-Value
20.25	0.000

According to Table 6, the P-value obtained from the paired sample t-test is 0.000, less than 0.05, demonstrating that the posttest value after using the E-worksheet is significantly greater than the pretest value before using the developed E-Worksheet. Therefore, the paired sample t-test concludes that Ha is accepted and Ho is rejected. This result confirms that the posttest value of scientific literacy after using the E-worksheet is greater than the pretest value, indicating that the developed interactive E-worksheet effectively enhances students' scientific literacy skills on chemical equilibrium material.

Overall, the results show a significant improvement in students' scientific literacy skills, with 86.11% of students scoring in the high category and 13.89% in the medium category on the posttest. Thus, the interactive E-worksheet has proven effective in improving students' scientific literacy skills on chemical equilibrium material and can be effectively utilised in educational settings to enhance these skills.

CONCLUSION

Based on the results and discussion, it can be concluded that the PBL-oriented interactive E-worksheet on chemical equilibrium material is feasible for enhancing students' scientific literacy skills, as evidenced by its validity, practicality, and effectiveness. The validity assessment of content, presentation, language, and design yielded a mode score of 4, categorising it as good. The practicality evaluation, based on student responses regarding content feasibility, appearance, presentation, alignment with scientific literacy, and engagement with PBL, achieved percentages of 85.18%, 87.5%, 92.6%, 87.22%, and 94.4%, respectively, all of which fall under the very practical criteria. The effectiveness, measured through the N-gain analysis, resulted in a score of 0.78, indicating high improvement, and the paired sample t-test produced a P-value of 0.000, confirming that the post-test scores were significantly higher than the pretest scores. Therefore, the PBL-oriented interactive E-worksheet on chemical equilibrium material effectively improves students' scientific literacy skills.

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