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Development of an E-worksheet Based on Problem-Based Learning with Prompting Question Technique on Chemical Equilibrium Material

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Abstract: Students' misunderstandings and low level of active involvement in learning chemical equilibrium, and the incomplete application of problem-based learning models. This study was motivated by students' misconceptions and low active involvement in learning chemical equilibrium material. In addition, the implementation of the problem-based learning model has not been fully realized, and students still experience difficulties in connecting and applying chemical concepts to everyday life. The purpose of this study is to develop a problem-based learning e-worksheet with prompting question techniques on chemical equilibrium material that is valid and practical. The method used is research and development (R&D) with the Plomp model, which includes the preliminary research and prototyping phases. Validity analysis techniques were analyzed using Aiken's V scale, and practicality analysis techniques were analyzed using a percentage formula. The validity analysis yielded an average score of 0.925, which is considered valid. The practicality test results showed that the e-worksheet is highly practical, with an average score of 94.375% from teachers and 89.38% from students. Based on the results of the study, it can be concluded that the development of an e-worksheet based on problem-based learning with prompting question techniques on chemical equilibrium material is valid and very practical.

Keywords: Chemical Equilibrium; E-worksheet; Problem-Based Learning; Prompting Question.

Introduction

Chemistry is a branch of science that has its own characteristics that distinguish it from other fields of science [1]. The majority of students find chemistry a challenging subject due to its abstract nature and complex concepts [2]. Difficulties occur because most of the chemistry material consists of concepts and calculations, so students are more likely to memorize than understand it.

One topic that is difficult for students to understand is chemical equilibrium, because most of the concepts are abstract [3]. Chemical equilibrium is related to various other chemistry topics and interacts with each other to understand the concept [4]. Based on the results of interviews with two chemistry teachers and the distribution of questionnaires to students at SMAN 1, 7, and 13 Padang, it was found that students had difficulty understanding chemical equilibrium material.

The Problem-Based Learning (PBL) model is one of the learning models suggested in the Merdeka Curriculum to be implemented in the teaching and learning process at school. The PBL model is a learning model that involves students with real problems from the beginning of learning as a stimulus. This approach encourages students to learn actively and work hard to solve the problems given [5]. PBL encourages learners to actively participate by inviting them to collaborate in solving problems [6]. This learning model is designed to be used effectively to encourage learners' creative thinking [7].

This model consists of 5 syntaxes, namely orienting students to the problem; organizing students to learn; guiding individual and group investigations; developing and presenting results; and analyzing and evaluating the problem-solving process [8]. A total of 55.69% of students from SMAN 1, 7, and 13 Padang experienced difficulties in connecting and applying chemical concepts in everyday life. Three of the six teachers in the three high schools have not implemented the PBL model in classroom learning, while the other three teachers have implemented it but not optimally due to the limitations of teaching materials that are less supportive.

To further build reciprocity between teachers and students and make the learning process more focused, researchers used the prompting question technique. In terms of meaning, prompting refers to the act of encouraging or guiding. In learning that uses prompting techniques, teachers guide students' understanding through a series of questions to solve problems or issues. In addition, students are also trained to prove the truth of a concept needed in problem-solving [9]. The application of this model and technique can create mutual interaction between teachers and students in the learning process so that students can easily absorb and understand the material. The application of the PBL model with prompting techniques involves students directly in the learning process. This can be seen from the increase in students' learning activities, where students who were previously passive became more active in learning [10].

Teaching materials play an important role in helping students understand the concepts learned [11]. One of the teaching materials that can be utilized by students is the Learner Worksheet. However, the worksheets used by

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students tend to be less efficient and less practical because they are still in the form of printed teaching materials [12]. Printed worksheets have several limitations, such as the lack of interactivity and the inability to present clear animations related to learning materials.

One innovation that can be used as an alternative to meet the needs of effective teaching materials is the development of an e-worksheet, given the high use of cell phones and laptops in the current era [13]. E-worksheets have many advantages and attractions compared to printed worksheets because they are equipped with video, audio, animation, and images that can increase students' enthusiasm and interest in learning. In addition, an e-worksheet is also more practical and economical because it does not require printing costs, and helps students stay motivated without getting bored easily [14]. One of the information technologies that can be utilized by teachers to convert worksheets in printed form into electronic versions is the Liveworksheet application. The questions can be designed in various forms, such as multiple choice, short answer, true/false statements, matching, and description questions [15].

The results of interviews with teachers at SMAN 1, 7, and 13 Padang showed that no teacher has utilized the e-worksheet in learning. The teaching materials used by teachers are still in the form of printed books, printed worksheet, and modules. The results of the questionnaire given to students revealed that they had difficulty learning because the teaching materials used by teachers were still monotonous. The teaching materials used by teachers have not used the PBL model and have not applied the prompting question technique. Students are more interested in worksheets that are colorful, equipped with pictures, apply PBL models, present problems related to everyday life, and use prompting question techniques.

Based on the above statement, the teaching material developed by the researcher, namely E-Worksheet Based on Problem-Based Learning with Prompting Question Techniques in Chemical Equilibrium Material, is a student worksheet containing learning material, images, and videos related to a subject and a series of questions about chemical equilibrium material. This instructional material is highly engaging and easily accessible anytime and anywhere. Since students enjoy using electronic devices, particularly smartphones and laptops, this medium will be highly effective in enhancing students' learning outcomes in the subject of chemical equilibrium. The benefits of this e-worksheet product for schools include providing a new learning experience for both students and teachers, and simplifying the process of delivering instructional content. The e-worksheet is equipped with engaging visuals, videos, and questions, making it more appealing for students to explore the subject matter.

Research Methods

The type of research used in this study is Research and Development (R&D). This research uses the Plomp development model introduced by Tjeerd Plomp. This model consists of three stages, namely Preliminary Research, Prototyping Phase and Assessment Phase [16]. However, this research is limited to the Prototyping Phase. After obtaining Prototype IV, which has been declared practical, large-scale field trials will be conducted. In this study, the assessment phase was not carried out due to time constraints, so further research in the form of testing the effectiveness of the e-worksheet in the classroom is needed. This research was conducted at SMAN 13 Padang and the Faculty of Mathematics and Natural Sciences, Padang State University in 2025. The research subjects were Chemistry Department Lecturers at Padang State University, Chemistry Teachers and students of class XII MIPA at SMAN 13 Padang.

Preliminary research consists of needs analysis, curriculum analysis, literature review, and conceptual framework development. The prototyping phase is obtained from the results of preliminary research, which will be used as the basis for conducting formative evaluation. There are several types of formative evaluation, namely self-evaluation, expert review, one-to-one evaluation, and small group. The results of the formative assessment will produce prototypes I, II, and III.

Prototype I was designed in the process of making a PBL-based e-worksheet with a prompting question technique in accordance with the independent curriculum. After the product was designed, a self-evaluation was carried out, and the results of prototype II were obtained. The purpose of self-evaluation is to see problems that are not immediately visible, such as writing problems, images, e-worksheet elements, and e-worksheet stages.

Furthermore, entering the prototype III stage, the e-worksheet was validated by 3 chemistry lecturers and 2 chemistry teachers of SMAN 13 Padang. In addition, individual evaluations were conducted by conducting interviews with three students who had different abilities. And if there are revisions and input from validators, it will be revised, which aims to improve the quality of the prototype.

After that, the practicality test was carried out in the form of product trials. 2 chemistry teachers and 9 students of class XII SMAN 13 Padang were involved in this practicality test. Based on the results of this practicality assessment, a valid and practical prototype IV e-worksheet product will be obtained.

The instruments used in this study are:

Teacher interview sheet and learner questionnaire

The instruments used to collect initial data in this study were teacher interview sheets and student questionnaires distributed in three different schools.

Validity questionnaire

The questionnaire was used to assess the validity of the content, construct, language and graphic components of the developed e-worksheet. This validity questionnaire was distributed to three chemistry lecturers at FMIPA UNP and two chemistry teachers at SMAN 13 Padang. Validators were given a number of questions with the aim of assessing each question systematically, and at the end, validators were given the opportunity to determine the final results of the research that had been conducted. Data analysis for the validity test was conducted using Aiken's V formula [17]. The Aiken's V formula used is as follows:

$$V = \frac{\sum s}{n(c-1)}$$

$$s = r - I_0$$

Description:
S = The validator's assigned score minus the lowest score in the category used
r = The validator's chosen category score
I_0 = The lowest score in the scoring category
n = The number of validators
c = The number of categories chosen by the validator

Table 1. E-worksheet validity level.

Scale Aiken's V	Validity
V < 0.8	Invalid
V ≥ 0.8	Valid

Practicality questionnaire

Questionnaires in the form of chemistry teacher responses and student responses to PBL-based e-worksheet with prompting question techniques were developed. The results of the assessment are data to determine the level of practicality of the e-worksheet developed. To collect information about the practicality of the worksheet in small groups, the following formula is used:

$$\text{NP} = \frac{\text{the number of scores obtained}}{\text{maximum number of scores}} \times 100\%$$

Table 2. Practicality Level Category

Value	Category
86% - 100%	Very practical
76% - 85%	Practical
60% - 75%	Practical enough
55% - 59%	Less practical
≤ 54%	Not practical

Results and Discussion

Preliminary Research

At the Preliminary research stage, several stages were carried out, namely needs analysis, curriculum analysis, literature review and conceptual framework development. The needs analysis was obtained by conducting interviews with chemistry teachers and distributing questionnaires to students at SMAN 1, 7, and 13 in Padang. Based on the results of the needs analysis, it is known that there are several problems in the chemistry learning process, especially with chemical equilibrium material, namely, the teacher has difficulty encouraging student activeness. The teaching materials used by teachers do not support learner-centered learning required by the independent curriculum, because the learning tools used by teachers are still limited to textbooks, printed teaching materials, and PowerPoint, and electronic teaching materials such as e-worksheet are not yet available in the learning process. At present, the teaching materials for the independent curriculum available are still very few and limited, and there are no electronic teaching materials, such as e-worksheet.

Curriculum analysis aims to understand the curriculum that is being applied by teachers, so that Learning Outcomes, Learning Objectives, and Learning Objective Flow can be determined to develop an e-worksheet. For Learning Outcomes, in accordance with the independent curriculum, Learning Outcomes. From this, 7 Learning Objective Flow were obtained based on the subject matter of chemical equilibrium, namely:

1. Students are able to explain reversible reactions and irreversible reactions
2. Students are able to explain the concept of chemical equilibrium
3. Students are able to explain the difference between homogeneous equilibrium and heterogeneous equilibrium
4. Students are able to calculate the concentration equilibrium constant (Kc)
5. Students are able to calculate the partial equilibrium constant (Kp)
6. Students are able to explain the factors that affect the occurrence of chemical equilibrium shifts
7. Students are able to analyze the application of the concept of chemical equilibrium in the industrial field

Literature review is done by looking for sources and references related to the research activities to be carried out, and looking for problems in this study. Some things can be used as sources, including chemistry textbooks, namely: Brady Jespersen, Raymond Chang, Petrucci Ralph H, and Silberberg; journals; articles, and so on, related to research activities.

In developing the conceptual framework, the researcher connects the concepts that are the object of this research. This stage was carried out after getting a problem based on the results of the needs analysis, curriculum analysis, and literature review conducted. Based on the needs analysis, it is known that chemical equilibrium material is difficult to understand, so an e-worksheet has been developed, which contains images and videos that help students better understand the material.

Prototyping Phase

Prototype I was obtained from the design at the preliminary research stage. The results of prototype I are an e-worksheet based on problem-based learning with prompting question techniques on chemical equilibrium material, which has several components, namely: Cover; Preface; Table of contents; Concept map; General information; PBL model; Instructions for use; e-worksheet components; Let's review; Learning activity sheets, and Bibliography. Here are some e-worksheet designs.

In prototype II, a formative evaluation of the results from prototype I was conducted. One type of formative assessment conducted is self-evaluation. The results of the evaluation conducted with reference to prototype I show that the developed e-worksheet has fulfilled the components of an e-worksheet.

Figure 1. Cover of e-worksheet.

Figure 2. General Information of the e-worksheet.

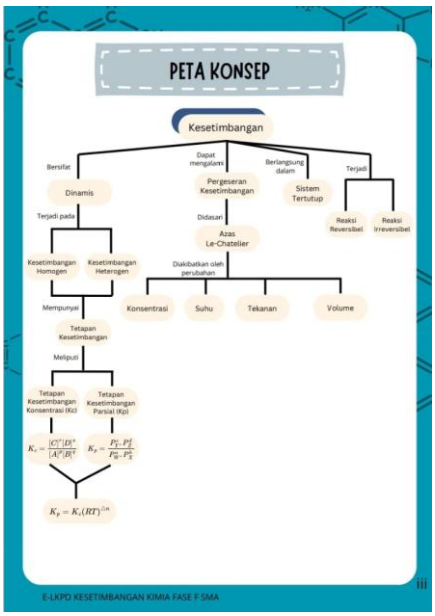

Figure 3. Concept Map.

Figure 4. Study Activity Sheet.

Prototype III was conducted with an expert review and a one-to-one evaluation. Validity testing aims to assess the extent to which the research instrument actually measures what it should measure and is able to accurately describe the data from the variables being studied [18]. The validation process was carried out by several experts with experience in evaluating the strengths and weaknesses of the developed product. In this study, validation was carried out by five validators, consisting of three chemistry lecturers from the Faculty of Mathematics and Natural Sciences, University of North Sumatra, and two chemistry teachers from SMAN 13 Padang. The validation results were then analyzed using Aiken's V formula. From the results of the data processing of the worksheet validation questionnaire, the following data were obtained:

Table 3. Results of validity data analysis.

Aspects assessed	V	Category
Content component	0.91	Valid
Presentation component	0.91	Valid
Language component	0.93	Valid
Graphics component	0.95	Valid
Overall average	0.925	Valid

The aspects assessed in the validity test include content, presentation, language, and graphics. In terms of content, the assessment covers the suitability of the Learning Outcomes, Learning Objectives, and Learning Objective Flow used in the e-worksheet. The e-worksheet also has material and concept descriptions derived from books and relevant sources, and is in line with the scope of the chemical equilibrium material being studied. The results of the data analysis show that the average validity for the content component reached 0.91, which is considered valid. This indicates that the developed e-worksheet presents material in the form of examples, phenomena, or problems that are relevant to the material, with the aim of motivating students to be more proactive in finding solutions to problems [19].

The presentation of the e-worksheet obtained an average V score of 0.91, which is classified as valid. This shows that the developed e-worksheet has been systematically arranged in accordance with the components of e-worksheet writing [20]. The development of e-

worksheets must also be carried out using trigger questions, following the stages of the PBL learning model, and systematically based on guidelines from the Ministry of National Education [21]. This is supported by [22] findings stating that students need problem-solving skills through the PBL model to overcome real problems they will face in the future.

The results of the analysis of the linguistic aspects of the e-worksheet show that the use of the Indonesian language in accordance with the rules and the clear delivery of material can facilitate students in understanding the content. The average V value of 0.93 is classified as valid, which aligns with the findings of [23], who emphasize the importance of using communicative language in the development of instructional materials. The ease of language in the e-worksheet supports students in easily understanding the material being studied [22].

The graphic aspects are assessed based on the design, font type and size, layout, image placement, and overall appearance of the e-worksheet. Visual appeal and physical quality of the appearance are important parts of the graphic assessment of the e-worksheet [24]. The results of the validation of the graphic design components indicate that the average V value falls within the valid category, at 0.95. This means that in terms of appearance, layout, and design, the developed e-worksheet is presented in an appealing manner. The font type, color, and size used are also clear [25]. The results of the assessment of all components show that the developed e-worksheet has an Aiken's V value of 0.925, which indicates that this product is valid as a whole.

One-to-one evaluation was conducted through interviews with three learners who had different abilities (high, medium, low) using an interview sheet. From the assessment of these students, it was found that the appearance of the design, presentation, use of language, and stages in the e-worksheet had helped students find and understand the concept of the material.

Prototype IV was obtained from the results of the practicality test questionnaire in the form of product trials of prototype III. The practicality test of the e-worksheet based on problem-based learning with the prompting question technique on chemical equilibrium material was conducted by two chemistry teachers and nine students in a small group of grade XII SMAN 13 Padang. Evaluation was conducted using a practicality questionnaire given to teachers and students, covering four aspects: ease of use, appearance, learning efficiency, and benefits of use. Results: The practicality data were processed and presented in percentage form, categorised according to practicality levels. The e-worksheet practicality questionnaire instruments were distributed separately to teachers and students. The results of the processing of the practicality assessment of the e-worksheet based on problem-based learning with prompting question techniques on chemical equilibrium material for teachers and students are in Tables 3 and 4.

In terms of ease of use, the developed e-worksheet received a practicality rating of 97.5% from teachers and 90.56% from students, both of which fall into the very practical category. This indicates that the e-worksheet is easy to understand and use for both teachers and students. This finding aligns with the research results by [26], which states that the e-worksheet is flexible because it can be used anytime and anywhere, and is easy to access and operate.

Table 4. Practicality results of the e-worksheet by teachers.

No.	Aspects assessed	Percentage	Category
1	Ease of Use	97.5%	Very practical
2	View	100%	Very practical
3	Learning Efficiency	86.66%	Very practical
4	Usage Benefits	93.33%	Very practical
Average		94.375%	Very practical

Table 5. Practical results of the e-worksheet by students.

No.	Aspects assessed	Percentage	Category
1	Ease of Use	90.75%	Very practical
2	View	87.30%	Very practical
3	Learning Efficiency	90%	Very practical
4	Usage Benefits	89.50%	Very practical
Average		89.38%	Very practical

The assessment of the e-worksheet display showed a practicality level of 100% from teachers and 87.40% from students, categorized as very practical. This indicates that visual features such as images and videos were successful in attracting and motivating students. These findings support the theory [27], which emphasizes the importance of visual appeal, especially the initial appearance, in the preparation of a worksheet. This is also in line with the opinion [28], which emphasizes that student interest is an important element in the success of the learning process.

The practicality assessment of teachers and students in terms of learning time efficiency obtained average scores of 86.66% and 90%, respectively, which are classified as very practical. Based on these results, it can be concluded that the e-worksheet developed using technology implementation is highly efficient, and students can adjust their pace in understanding the material according to their individual needs. This finding is supported by research [29] stating that the use of technology in learning can improve time efficiency during the learning process.

Based on an assessment of its usefulness, the e-worksheet that was developed received a score of 93.33% from teachers and 89.44% from students, indicating a very high level of practicality. This shows that the use of the developed product can help and facilitate students in understanding the concepts and exercises provided, which are useful for strengthening students' understanding. This finding is reinforced by research [30] that practical e-worksheet can improve students' mastery of material and problem-solving skills. The use of images and videos relevant to the material enables students to visualize the material and convey the content well [31]. Overall, the practicality of PBL-based e-worksheet with prompting question techniques in chemical equilibrium material showed very satisfactory results, with a practicality percentage of 94.375% from teachers and 89.35% from students.

Conclusion

This research produces an e-worksheet based on problem-based learning with prompting question techniques

on chemical equilibrium material developed using the Plomp development model. The validity results show that the e-worksheet produced is valid with a value of V = 0.925. And the practicality test by teachers and students obtained a percentage of 94.375% and 89.38% with a very practical category. This product is recommended for further testing of its effectiveness in subsequent research, so it can be used in actual teaching. Before conducting effectiveness testing, it is recommended to revise some images and videos to make them better and more engaging, and to display the 3D form of the material contained in the e-worksheet.

Author's Contribution

Putry Amanda Lubis: Research design, data analysis, and completion of scientific article writing. Dwi Finna Syolendra: Provided constructive suggestions for the perfection of the writing.

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