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Analysis of the Effectiveness of PBL-Oriented Interactive Electronic Student Activity Sheets Development on the Material of Factors Affecting Chemical Equilibrium to Improve Students' Science Literacy Skills

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Abstract: The science literacy skills of Indonesian students are still low based on the results of PISA 2022. Chemical equilibrium material is very important, and understanding chemical equilibrium is a prerequisite for understanding subsequent materials. One of the efforts to improve understanding of chemical equilibrium material is applying a student-centred learning model, the PBL model. PBL can also improve students' science literacy skills. Thus, research was conducted to develop PBL-oriented interactive electronic student activity sheets on chemical equilibrium material to improve students' science literacy skills. This research aims to describe the effectiveness of interactive E-LAPD as a learning media for improving students' science literacy skills. Research and development (Research and Development) is the type of research used. The research design used in this research is the 4-D model development research design according to Thiagarajan's 4-D model, which consists of the define, design, develop, and disseminate stages. The instrument used in this research is a pretest and posttest sheet of science literacy skills to measure students' science literacy skills. This research used a limited trial with a one-group pretest-posttest research design. The limited trial was conducted at SMAN 1 Kedamean with 36 class XI MIPA 3 students. The effectiveness results analyzed using the paired sample t-test obtained a p-value of 0.000, which indicates that the posttest value after learning using interactive E-LAPD is greater than the pretest value before learning using interactive E-LAPD. Thus, PBL-oriented Interactive E-LAPD can be said to improve students' science literacy skills.

Keywords: Chemical Equilibrium; Interactive E-LAPD; Science Literacy Skills.

Introduction

The digital era is experiencing rapid development, one of which is in science and technology. The rapid development of technology makes it a challenge for the world of education to always be ready in this era [1]. In realizing an increasingly advanced education, it must be supported by human resources. One way to address this is with science literacy [2]. According to the Organization of Economic Cooperation and Development (OECD), Indonesia's ranking in PISA 2022 was 68th out of 81 participating countries, with a score of 383. On the science literacy score, Indonesia experienced a decrease of 13 points from PISA 2018 [3]. Based on the results of PISA 2022 show that the science literacy skills of students in Indonesia are still below average when compared to international scores.

This is reinforced by Tulaiya and Wasis' research on two schools in Sumenep District. In the first school, the average was obtained in the competency domain of explaining phenomena scientifically, the competency of designing and evaluating scientific investigations, and the competency of interpreting data and scientific evidence, respectively by 34.04%, 14.22%, and 60.10%, which are included in the low to medium category [4]. In the second school, the average percentage obtained on the competence of explaining phenomena scientifically, the competence of designing and evaluating scientific investigations, and the competence of interpreting data and scientific evidence, respectively, amounted to 17.95%, 10.81% and 27.88%, which were included in the low category [4]. Maulida and Sunarti's research conducted at one of the high schools in Lamongan Regency shows that the science literacy skills of students are 3% in the very high category, 3% in the high category, 24% in the medium category, 3% in the low category, and 67% in the very low category [5]. Research in one of the schools in Gresik City showed that the average science literacy competency score in the very low category was 23.6% [6].

One material studied in high school chemistry is chemical equilibrium. Chemical equilibrium is a fundamental topic in high school chemistry that covers the types of reactions equilibrium and the factors affecting them [7]. Chemical equilibrium material has three representation levels: microscopic, macroscopic, and symbolic. Understanding chemical equilibrium is needed as a precursor to understanding further materials such as acid-base, salt hydrolysis, buffer solution, solubility and product of solubility [8]. In addition, research states that there is still a lack of learning media that students can easily understand the subject matter of chemical equilibrium [9]. Thus, efforts are needed so that students can understand chemical equilibrium material in depth so that students can receive and understand further material easily.

One of the efforts to understand chemical equilibrium material, especially the factors that affect the direction of

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shifting chemical equilibrium in students, is to apply a student-centred learning model. Following Permendikbud number 103 of 2014, the characteristics of 21st-century learning require student-centred learning. One learning method with learner-centred characteristics is the Problem-Based Learning (PBL) model. This is reinforced by research showing a significant difference in concept understanding between students who learn with the PBL model and students who learn with the direct learning model [10]. The PBL learning model can not only improve students' understanding of concepts but also improve students' science literacy skills. Based on Kurniawati and Hidayah's research, the percentage value of classes using the PBL learning model can help students' scientific literacy skills increase to 82.93% [11]. The PBL learning model is a learning process that has the characteristics of learning starting with giving problems that have a context with the real world, active group learning, formulating problems and identifying their knowledge gaps, researching and finding material related to the problem and the solution to the problem [12]. Learning media is needed to facilitate student delivery in applying a learning model. Regulation of the Minister of National Education (Permendiknas) No. 41 of 2007 concerning learning process standards that teachers are expected to use learning media other than textbooks as one of the learning resources. Therefore, the availability of learning media such as LAPD can be one of the learning resources.

One of the 21st Century skill requirements is Information media and technology skills, so to fulfil these demands, innovation is needed in the development of learning media. One innovation in learning media development can be an interactive Electronic LAPD (E-LAPD). Interactive E-LAPD is a student worksheet digitally packaged with various features to assist independent learning activities. It contains material abstractions and questions to guide students in understanding the material [13].

Based on the description above, other innovations are needed to improve students' science literacy skills by developing feasible learning media that can improve students' science literacy skills. Thus, a research study was conducted titled "Analysis of the Effectiveness of Problem-Based Learning-Oriented Interactive E-LAPD Development on the Material of Factors Affecting Chemical Equilibrium to Improve Students' Science Literacy Skills." This study aims to describe the effectiveness of interactive E-LAPD as a chemistry learning media to improve students' science literacy skills based on pretest and posttest results of science literacy skills.

Research Methods

Research and development (Research and Development) is the type of research used. According to Thiagarajan, the research design used in this research is the 4-D model development research design, which consists of the stages of defining, designing, developing, and disseminating [14]. However, this research is only limited to the development stage. The instrument used in this research is a pretest sheet and a posttest sheet of science literacy skills is to measure the science literacy skills of students. In this research, limited trials were conducted with a product trial design, namely one group pretest-posttest, to determine the effectiveness of Interactive E-LAPD. The limited trial was conducted at SMAN 1 Kedamean with 36 class XI MIPA 3 students. Research data were obtained through test techniques.

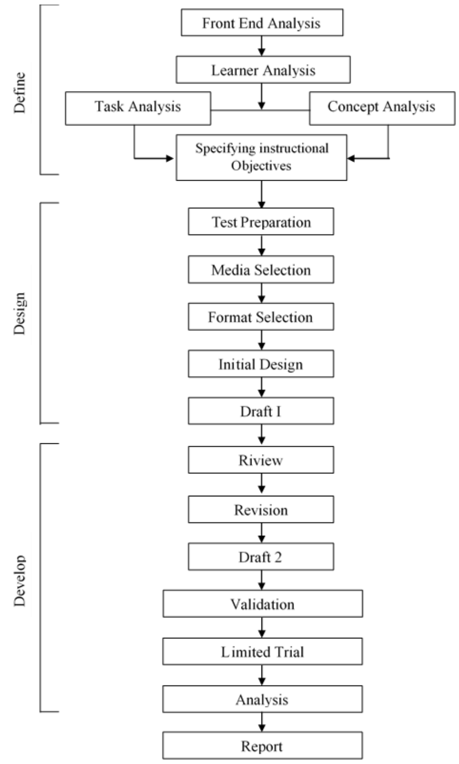

Figure 1. 4-D design modified to 3-D

At the define stage is a front-end analysis, learner analysis through task and concept analysis, and the specification of learning objectives using literature and field studies. The literacy research was conducted by analyzing the curriculum and material concepts used. In the field of research, namely, the state of students is analyzed. This stage is done to design E-LAPD products according to the needs of students.

Test preparation, media selection, format selection, initial design, and Draft 1 are at the design stage. Test preparation is conducted by preparing a pretest and posttest of science literacy skills following the science literacy domain to be improved, namely, the knowledge domain consisting of content knowledge, procedural knowledge, and epistemic knowledge. Media selection aims to identify learning media that suit the needs of students. In contrast, format selection consists of several things, such as designing learning content, selecting learning resources, and making E-LAPD designs, which include layout design, writing, and images. The initial design is the design of the E-LAPD product developed, which has been completed thoroughly before being reviewed by chemistry lecturers. The results at this stage are called Draft 1.

The next stage is the development stage. At this stage, Draft 1 from the design stage was reviewed by chemistry lecturers so that the suggestions obtained were used as improvement materials to obtain Draft 2. Then, Draft 2 was validated by two chemistry lecturers and one chemistry teacher. The valid PBL-oriented interactive E-LAPD will be used in a limited trial. In the limited trial, pretest and posttest of science literacy skills were conducted.

The pretest and posttest results of science literacy were analyzed using the paired sample t-test. The paired sample t-test is an analysis involving two measurements on the same subject against a certain influence or treatment. This test is used when two data sets are measured on the same subject before and after treatment [15]. A normality test is conducted before the paired sample t-test is conducted to see whether the data is normally distributed. A normality test is a requirement when conducting a paired sample t-test analysis. The Shapiro-Wilk normality test was used because the sample was <50. The normality test was conducted using the Minitab application with the following decision-making basis.

- If the p-value > 0.05, the data will be declared normally distributed.
- If the p-value < 0.05, the data is declared not normally distributed [16].

If the obtained p-value is> 0.05, then the data is normally distributed [17]. Furthermore, a paired sample t-test was conducted to determine the difference in science literacy skills before and after using the developed interactive E-LAPD. The hypotheses proposed are as follows:

$$H_0: \mu_1 \leq \mu_2$$
$$H_a: \mu_1 > \mu_2$$

[18]

H_0 states that the posttest value of science literacy after using E-LAPD is smaller or equal to the pretest value of science literacy before using E-LAPD, and H_a states that the posttest value of science literacy after using E-LAPD is greater than the pretest value of science literacy before using E-LAPD.

Results and Discussion

This research aims to describe the effectiveness of PBL-oriented interactive E-LAPD on chemical equilibrium material in improving students' science literacy skills. This research has been conducted in accordance with the steps in the 4-D model development research design according to Thiagarajan, which is limited to the development stage.

Define

This stage aims to provide a learning design. The defining stage consists of five stages, namely, front-end analysis, learner analysis, task analysis, concept analysis, and learning objective analysis. A front-end analysis was conducted by reviewing related literature and school observations. In the front-end analysis, it is known that science literacy must be practised so that learning becomes more meaningful. Learner analysis is carried out to know the characteristics of students, namely academic ability, age and cognitive development, students' experience in previous chemistry learning, motivation towards chemistry subjects, and abilities possessed by students. The subjects of this research are students aged 16-18 years who have not received chemical equilibrium material. At this age, students are in the formal operational phase, where students are considered capable of thinking about hypothetical situations or suppositions. In this phase, students' reasoning capabilities increase, and they can think about more than one dimension of abstract characters [19]. In the task analysis, the main tasks are obtained by students in learning activities. A concept map of chemical equilibrium material that students will learn is produced in concept analysis. Analysis of learning objectives results in learning outcomes and flow of learning objectives following the independent curriculum.

Design

Science literacy tests based on predetermined learning objectives are first prepared at the design stage. Then, the content materials for E-LAPD are collected in the form of images, videos, or animations that follow chemical equilibrium material. In designing problem-based learning-oriented E-LAPD to improve science literacy skills, there are three domains of science literacy combined with five phases of problem-based learning. The E-LAPD was designed directly using the Canva website. E-LAPD was developed and consists of three parts, namely temperature factors, concentration factors, and volume and pressure factors. The result of the design stage is called draft 1. E-LAPD can be accessed via PC, smartphone, or tablet. The following is a view of the E-LAPD cover when accessed via smartphone.

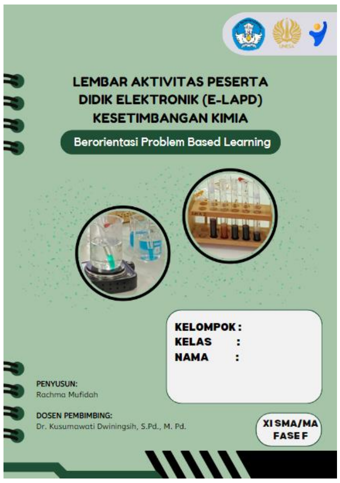

Figure 2. Interactive E-LAPD Cover

This research aims to design an interactive E-LAPD that can effectively improve science literacy skills. The interactive E-LAPD is designed with science literacy components consisting of context domains, knowledge domains, and competency domains. The design of E-LAPD to improve science literacy skills is detailed as follows.

Figure 3. Context Domain

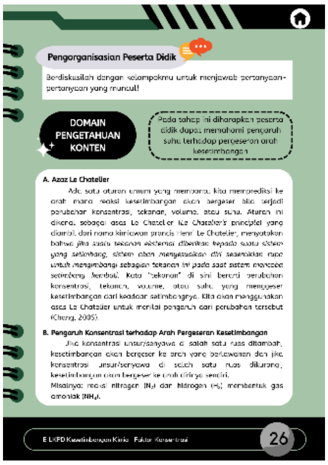

Figure 4. Knowledge Domain

Figure 5. Competency Domain

Develop

The purpose of the development stage is to obtain interactive E-LAPD learning media that can be used to improve students' science literacy skills. Draft 1, obtained from the design stage, was reviewed by chemistry lecturers. Suggestions and comments obtained were used as improvement materials to obtain Draft 2, which would be validated by two chemistry lecturers and one chemistry teacher. The valid interactive E-LAPD was then tested on a limited trial.

The limited trial stage aims to determine the effectiveness of the development of PBL-oriented interactive E-LAPD on chemical equilibrium material to improve students' science literacy skills in terms of pretest and posttest. The initial stage in this trial was a pretest to determine the initial ability of students' science literacy. The pretest questions given to students consisted of 10 multiple choice questions of various domains of science literacy to be improved, namely the domains of knowledge, context, and competence. In the next meeting, students participated in learning activities using PBL-oriented interactive E-LAPD on chemical equilibrium material. The interactive E-LAPD trial was carried out up to 3 meetings because the E-LAPD developed consisted of three sub-E-LAPDs: E-LAPD 1 temperature factor, E-LAPD 2 concentration factor, and E-LAPD 3 pressure and volume factors.

In the trial activity, students accessed the interactive E-LAPD developed through smartphones. Students are divided into six groups, each comprising six students. Each group that has successfully accessed interactive E-LAPD analyzes authentic problems, identifies problems, formulates problems, and makes hypotheses. This follows the focus of PBL learning, namely the existence of problems chosen so that students not only learn concepts related to the problem but also scientific methods to solve the problem [20]. In this activity, students are trained in science literacy in the competency domain of explaining phenomena scientifically. Besides that, the problems presented can improve students' science literacy skills in the context domain.

Students experiment while recording the results. After the experiment is complete, students analyze and make conclusions. During this process, students are trained in science literacy in the epistemic knowledge domain. At the end of the trial activity, students formulate conclusions from the problem-solving process. At this stage, students are trained in science literacy in the competency domain of interpreting data and scientific evidence.

The pretest is conducted after students take part in learning using PBL-oriented interactive E-LAPD to determine its effectiveness. The effectiveness of the developed E-LAPD was measured using a pretest-posttest sheet of science literacy skills consisting of 10 multiple-choice questions. The pretest sheet is given before using interactive E-LAPD, which aims to determine the initial ability of students to learn science literacy. In contrast, the post-test sheet is given after using interactive E-LAPD developed to determine students' science literacy ability after using interactive E-LAPD. The results of the pretest and posttest are presented as follows.

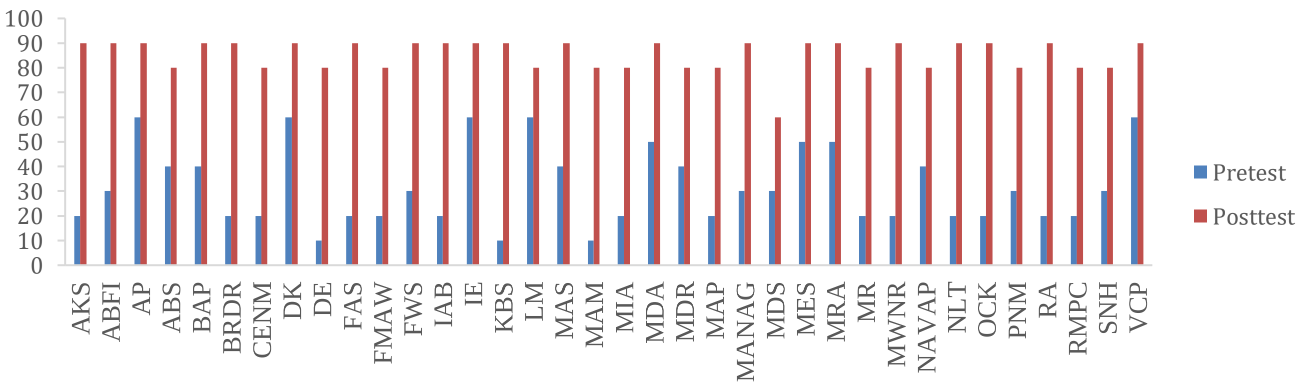

Figure 6. Improving Science Literacy Skills of Students

Based on Figure 6, it can be seen that all students experienced an increase in science literacy skills based on pretest and posttest results. The pretest and posttest results of science literacy were analyzed using the t-test. The t-test used is the paired sample t-test is used to compare the average of two related samples taken from the same subject [15]. This test method is used to assess the effectiveness of the treatment, characterized by a difference in means after and before treatment. The results of the science literacy pretest-posttest were first analyzed using a normality test to determine the normal distribution of data. The normality test used is Shapiro-Wilk because the sample is less than 50. The normality test is carried out using the Minitab application with the basis for decision-making, namely, if the p-value >0.05, then the data is normally distributed [17]. The results of the normality test are presented as follows.

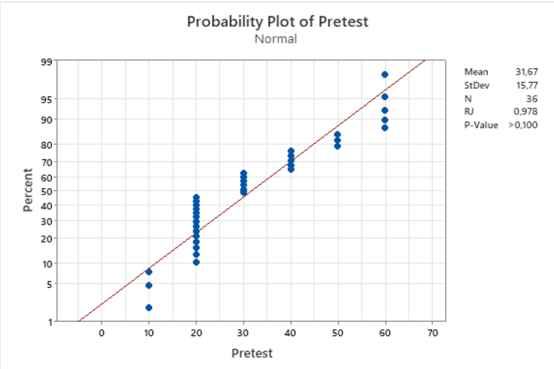

Figure 7. Result of Pretest Data Normality Test

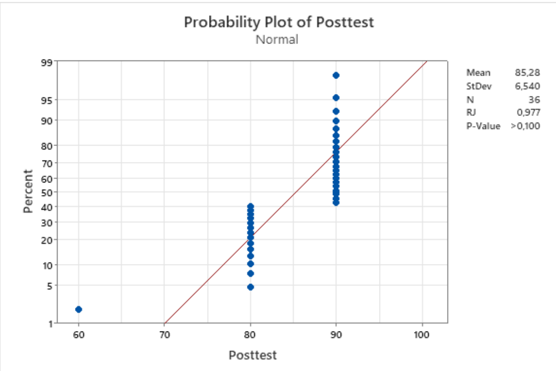

Figure 8. Result of Posttest Data Normality Test

Based on Figure 7 and Figure 8, it is known that the P-value obtained is 0.100, so that >0.05, the pretest and posttest data can be said to be normally distributed. The next step is the paired sample t-test using the Minitab application. Hypothesis H0 proposes that the post-test science literacy value after using E-LAPD is less than or equal to the pretest science literacy value before using E-LAPD. In contrast, Ha proposes that the post-test science literacy value after using E-LAPD is greater than the pretest science literacy value before using E-LAPD. If the p-value <0.05 means H_0 is rejected, and H_a is accepted, the posttest value after using E-LAPD is greater than the pretest value. In contrast, if the p-value >0.05 means H_0 is accepted and H_a is rejected, the posttest value is smaller or equal to the pretest value. The E-LAPD developed can be said to be effective for improving students' science literacy skills if the pretest and posttest results obtain a p-value <0.05. The paired sample t-test results are as follows.

Test

Null hypothesis H_0: μ_difference = 0
Alternative hypothesis H_1: μ_difference > 0

T-Value	P-Value
20,25	0,000

Figure 9. Result of Paired Sample T-test

Based on Figure 9. the p-value was 0.000, so <0.05, which shows that the posttest value after using E-LAPD is greater than the pretest value before using the developed E-LAPD. The paired sample t-test concludes that Ha is accepted and Ho is rejected. Ho means that the posttest value of science literacy after using E-LAPD is smaller or equal to the pretest value of science literacy before using E-LAPD. Meanwhile, Ha means that the posttest value of science literacy after using E-LAPD is greater than the pretest value of science literacy before using E-LAPD. Based on the t-test results conducted with the acquisition of p-value <0.05, the interactive E-LAPD developed can improve students' science literacy skills.

In learning using interactive LKPD of chemical equilibrium, students are trained in their science literacy skills by using interactive LKPD of chemical equilibrium that has been prepared following science literacy competencies, namely the knowledge domain, competency domain, and context domain. The context domain presented invites students to think about authentic problems related to science so that students will be more challenged to learn. The science literacy domain appears in each PBL phase. In the problem orientation phase, context and competency domains invite students to explain phenomena scientifically. The knowledge domain is found in the phase of organizing learners. There is a competency domain and an epistemic knowledge domain in the phase of guiding individual and group investigations. In contrast, there is a competency domain in the phase of developing and presenting work results. There is a competency domain in the last phase of PBL, namely analyzing and evaluating the problem-solving process.

Overall, based on the results described show that the students' science literacy skills have increased based on the science literacy posttest scores, namely 86.11% in the high category and 13.89% in the medium category. This aligns with one of the research results, which showed that the experimental class that applied the problem-based learning model had better science literacy post-test results than the control class [11]. Thus, interactive E-LAPD can improve students' science literacy skills on chemical equilibrium material and can be used in learning to enhance students' science literacy skills.

Conclusion

Based on the results and discussion, it can be concluded that the PBL-oriented interactive E-LAPD on chemical equilibrium material to improve students' science literacy skills is declared effective to improve students' science literacy skills. The pretest and posttest results were analyzed using a paired sample t-test, and a p-value of 0.000

was obtained, which indicates that the posttest value is greater than the pretest value. Thus, PBL-oriented interactive E-LAPD on chemical equilibrium material can improve students' science literacy skills.

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