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Development of Electronic Student Worksheets (E-Worksheets) Based on Problem-Based Learning to Train The Critical Thinking Abilities of Students on Acid-Base Topics

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Abstract: The purpose of this study is to develop a problem-based learning (PBL) editorial electronic student worksheet (E-Worksheet) that trains using liveworksheets of student critical thinking about acid base issues in terms of effectiveness, practicality and effectiveness. This study follows a research and development (R&D) approach using the ADDIE model, which consists of five phases: Analysis, Design, Development, Implementation, and Evaluation. This research was conducted at Senior High School 1 Krembung in class XI-2 with a class of 34 students. The results showed that the content validity and components of the E-Worksheet received a score of 3 and placed them in a good category. The practicality of the E-worksheet was based on related student activities in the first and second sessions, achieving a rate of 93.33% and 95.55% in the highly practical category. Furthermore, the practicality of students who answer 98.17% surveys is supported by very practical categories. The E-Worksheet effectiveness was carried out by assessing improvements in critical thinking skills based on student pretest and N-gain scores derived from post values. The results showed an improvement of 1 from 0.66 in the medium and high category. Data from pretest and postest results were then analyzed using the normality test and resulted in a significance of 0.621 or 0.231, resulting in a significance of > 0.05, so the data is distributed normally. Additionally, it was tested using a paired sample T test, which received a significance value of 0.000. Based on these results, we can draw the conclusion that E-worksheets may be feasible using liveworksheet-oriented problem-based learning to train students' critical thinking skills into acid-based problems.

Keywords: *E-Worksheet, Problem Based Learning (PBL), Critical Thinking Skills, Acid-Base*

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I. INTRODUCTION

The independent curriculum is applicable to all forms of learning, including chemistry education. Chemistry is a branch of science that holds a significant role because through chemistry, various phenomena of life can be logically explained. In chemistry, there are three aspects, namely macroscopic (observable properties), microscopic (particles that make up substances) and symbolic (substance identity). One of the materials in chemistry subjects in class XI Senior High School that is considered difficult because the concept of the material is quite complex and abstract is acids and bases [1]. Acids and bases are chemistry learning whose application is found in everyday life. Chemistry learning on acid and base material can be done by connecting the mastered concepts with the phenomena being studied [2].

In the 21st century, one of the learning skills that understudies have to be ace is critical thingking. Critical thingking could be a cognitive perspective that capacities to distinguish a issue. Critical thinking skills aim to make decisions and solve problems in a structured and creative way to find different alternative solutions [3]. Basic considering abilities can be connected in learning chemistry, one of which is in acid-base fabric. This is due to the characteristics of acid-base materials that require experiments or practical activities by dealing directly with phenomena in everyday life. With learning that seeks solutions to problems in everyday life, it can make students understand more about the concepts obtained [4]. This statement is supported by previous research that acid-base material has concepts that need to be remembered and understood, and practicum activities related to everyday life are necessary for students to better understand the concepts learned [5]

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Based on the facts that occurred in the field with 27 respondents at Senior High School Negeri 1 Krembung, the comes about of the rate of the normal capacity of understudies to solve test questions on interpretation indicators were 36.6%, analysis was 46.3%, evaluation was 37.0%, and inference obtained the lowest percentage result of 29.6%. Based on the explanation above, the learning activities of acid-base material really need the ability of students to learn in terms of interpreting, analyzing, and concluding [6]. Here, these skills are essential components of critical thinking, including interpretation, analysis, inference, evaluation, explanation, and self-regulation [7].

The right learning show to be connected in learning acid-base chemistry fabric to prepare students' basic considering aptitudes is the problem-based learning (PBL) show. The problem-based learning (PBL) demonstrate is an approach in which understudies learn through authentic true issues [8]. This is supported by previous research by Suci & Nasrudin (2018), which indicates that the implementation of the PBL learning model can enhance students' critical thinking skills [9]. In expansion to the application of a problem-based learning model, the practice of critical thinking skills can also be supported by an instructional material or an electronic student worksheet (E-Worksheet). To develop contextual and interactive electronic student worksheet (E-Worksheet) by loading audio and video, a website called liveworksheet can be used [10]. Based on the over portrayal, an E-worksheet advancement investigate will be carried out in understanding with the requirements of understudies, to be specific the advancement of the problem-based learning arranged electronic understudy worksheet (E-Worksheet) utilizing liveworksheet to prepare students' basic considering aptitudes on acid-base material.

II. LITERATURE REVIEW

A. *Electronic student worksheet using liveworksheet*

Electronic Student Worksheet (E-Worksheet) are Internet-based learning tools that are systematically arranged in certain lessons presented in electronic form. Liveworksheets is one of the electronic media in which there are images, text, videos and animations that are more effective so that students do not feel bored quickly to help students learn in a directed manner [11].

B. *Problem Based Learning Model (PBL)*

The problem-based learning (PBL) learning model is learning based on authentic problems [12]. Since the issues utilized within the PBL model are authentic, students can explore real-life learning experiences [13]. The syntax or stages of the problem-based learning model are divided into five: (a) situating understudies to the issue; (b) organizing understudies to memorize; (c) directing bunch examinations; (d) creating and displaying test comes about; and (e) analyzing and assessing a problem-solving handle [14].

C. *Critical Thinking Skills*

Critical thingking abilities are one of the higher-order considering aptitudes required to create 21st century abilities [15]. These abilities play a crucial role in daily life, particularly in the field of education. Additionally, critical thinking skills assist in recognizing and addressing problems more efficiently and effectively [16]. Key aspects of critical thinking skills encompass interpretation, analysis, inference, evaluation, explanation, and self-regulation [7]. In this study, four indicators are applied, namely interpretation, analysis, evaluation, and inference. Consistent with previous research, the four indicators are effectively implemented in acid-base materials by applying acid-base concepts to everyday life [17].

D. *Acid-Base Material*

Acids and bases are chemical compounds found in everyday life and include two important classes of chemicals. Acids are hydrogen-containing compounds that dissolve in water to produce hydrogen. Meanwhile, bases can increase the concentration of hydroxide ions in aqueous solvents. Acids and bases have different properties, so the difference can be used to identify the nature of a solution [18]. How to determine the nature of a solution using an acid-base indicator. Acid-base indicator is a substance that causes color changes in acidic and basic solutions. Acid-base indicator is also a substance that can change its color or form fluorescent usually called turbidity at a certain pH trajectory [19]. According to their type, acid-base indicators are divided into two, namely natural indicators and artificial indicators. The measurement of acidity or basicity of a solution is called pH (power of hydrogen). The hydrogen power (pH) of a solution can be interpreted as the negative logarithm of the hydrogen ion concentration (in moles per liter) [20].

III. METHODS

This research falls under the category of Research and Development (R&D). It follows the ADDIE (Analyze, Design, Development, Implementation, and Evaluation) development model model as its framework. This research is development of the problem-based learning oriented electronic student worksheet (E-Worksheet) using liveworksheet to train students' critical thinking skills on acid-base material. The application of this research was conducted on students of class XI-2 at Senior High School 1 Krembung with a class of 34 students. This study aims to determine the feasibility of electronic student worksheet based on validity, practicality, and effectiveness.

A. *Validity*

Validity is assessed based on content and construct criteria (language, presentation, and graphics). The validation process was carried out by two lecturers from the Chemistry Education program at Unesa and a chemistry teacher. The likert scale scores are shown in the table below.

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Table 1 Likert Scale

Score	Category
3	Good
2	Good Enough
1	Not Good

The data obtained is then searched for the mode value. The most frequently occurring score, also known as the mode, represents the validity value. Aspects are said to be valid if the mode obtained is greater than 3 with a good category [21].

B. Practicality

The practicality is evaluated based on the student response questionnaire and their activities. The score for the student response questionnaire is determined using the Guttman scale criteria, as shown in the table below.

Table 2 Guttman Scale

Statement	Answer	Score
Positive	Yes	1
	No	0
Negative	Yes	0
	No	1

The collected data was analyzed by calculating the percentage using the formula provided below.

$$Percentage\ of\ practicality = \frac{Total\ Score\ Obtained}{Maximum\ Score} \times 100\%$$

The percentage results of practicality are interpreted into a score with the corresponding categories in the following table.

Table 3 Percentage Criteria

No	Percentage (%)	Category
1.	81-100	Very Practical
2.	61-80	Practical
3.	41-60	Practical Enough
4.	21-40	Impractical
5.	0-20	Very Impractical

According to the table above, it can be concluded that it is considered practical for use if the percentage reaches ≥ 61%, falling into the practical or highly practical category [21].

Students activities during learning are analyzed based on the average observation results of 3 observers using the formula below.

$$Pecentage = \frac{\sum Frequency\ of\ student\ activities\ that\ appear}{\sum Total\ Activity\ Frequency} \times 100\%$$

Student engagement in learning is considered effective and supports practicality if the percentage of relevant student activities reaches ≥ 61%, falling within the practical or highly practical category [21].

C. Effectiveness

Effectiveness is indicated by the increase in score, which is achieved when the post-test score is higher than the pre-test score. Data analysis of the critical thinking skills component is calculated using the following formula.

$$\%\ \text{Critical Thinking Skill} = \frac{Score\ Obtained}{Total\ Score} \text{ x } 100\%$$

The enhancement of students' critical thinking skills is determined by analyzing the difference between pretest and posttest scores, utilizing the N-gain calculation presented below.

$$\langle \text{Score Gain} \rangle = \frac{score\ postest - score\ pretest}{maximum\ score - score\ pretest}$$

Based on the obtained N-gain calculation results, the values are then interpreted according to the N-gain score criteria presented in the table below.

Table 4 N-Gain Score

N-Gain Score	Criteria
$\langle g \rangle \geq 0{,}7$	High
$0{,}3 \leq \langle g \rangle < 0{,}7$	Medium
$\langle g \rangle < 0{,}3$	Low

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Based on the N-gain score table over, in the event that the N-gain esteem in measuring the comes about of moving forward basic considering abilities comes to ≥ 0.7 with tall criteria or ≥ 0.3 with medium criteria [22].

Then, the normality test is performed using the SPSS Shapiro-Wilk program to determine whether there is a difference between normally or abnormally distributed pretest and postest scores. The data is normally distributed if the significance value is > 0.05, so it can proceed to the next test, which is the paired samples t-test. Conversely, if the data do not follow a normal distribution, the analysis is conducted using a non-parametric statistical method known as the Wilcoxon Signed Rank test. The paired samples t-test was performed using the SPSS program. The paired sample t-test was used to determine the significance of the difference between the pretest and posttest scores. The difference between pretest and posttest scores is seen from the significance value <0.05, which means that H_0 is rejected and H_1 is accepted, so learning is said to be effective.

IV. RESULTS AND DISCUSSION

A. Analyze

The analysis of the problem is conducted to identify the issues faced by the students in learning chemistry and the learning tools needed by the students by conducting field studies in the target school, namely Senior High School 1 Krembung. The researchers distributed questionnaires which included pre-research questionnaires, critical thinking skills tests to the students of Grade XI, and interview sheets to the chemistry teachers. Based on the results of observations obtained that students are less trained in critical thinking skills in acid-base material, as evidenced by the method used by the teacher when teaching chemistry in class only using the lecture method, so that students are less active, critical, and lack of interest in learning students in learning acid-base material. According to Piaget's cognitive learning theory, states that learning that encourages the thinking process of students can build knowledge, so that students will be actively involved in obtaining information and building their own knowledge [16].

The needs analysis is used as a reference in the development of the PBL-oriented electronic student worksheet using liveworksheet on acid-base material. The results of the pre-research questionnaire showed that 70.4% of students found acid-base material challenging to understand in chemistry learning. This difficulty arises due to the heavy emphasis on memorization and theoretical concepts. The learning media utilized by the teacher primarily consists of printed books. This is supported by the fact that 66.6% of students reported having difficulty comprehending acid-base material effectively when relying on the teacher's chosen learning media, which is printed books. Based on the results of the above pre-research, so the researchers developed the problem-based learning oriented electronic student worksheet using liveworksheet to train students' critical thinking skills on acid-base material. In line with the research conducted by Astuty (2018), it is proved that PBL-based student worksheet can improve critical thinking skills [23].

B. Design

Based on the data obtained after the analysis stage by analyzing the problems and needs, the design stage can then be carried out. The product developed in this study is an PBL-oriented electronic student worksheet using liveworksheet to train students' critical thinking skills on acid-base material. The electronic student worksheet is designed based on the indicators to be achieved, namely students are expected to train their critical thinking skills. In this study, two electronic student worksheet were developed with different sub-materials in each session. The first electronic student worksheet contains the natural acid-base indicator sub-material that is done in the first session, while the second electronic student worksheet contains the acidity (pH) sub-material that is done in the second session.

C. Development

Development is the stage where products and research instruments are developed and validated. At this stage, the development of electronic student worksheet using liveworksheet and the development of research instruments that have been revised based on comments, suggestions and assessments from the results of expert reviews and validators. The development activities were carried out in the following stages.

- *Development of Electronic Student Worksheet with Liveworksheet*

Electronic student worksheet development is performed using the Liveworksheet website, which is accessible via the Internet. The results of electronic student worksheet development can be easily accessed through the liveworksheet link and used with a laptop or mobile phone connected to the internet network.

- *Research Instrument Development*

The development of research instruments is based on the goals of product feasibility, including determining validity, practicality, and effectiveness. The validation sheet consists of content and construct validation by presenting several aspects and a rating scale of 1-3. Validity is seen from the supervisor's review sheet and validation from the validator team. Practicality results were obtained from a learner response questionnaire and a learner activity observation sheet. The observation sheet developed 9 aspects of learner activity, including 12 relevant activities and 1 irrelevant activity, where learner activity during learning was calculated per 3 minutes. The response questionnaire was developed with 29 questions, each of which presented positive and negative questions with a rating scale of "yes" and "no". The effectiveness results were obtained from the pre-test and post-test by the students, with each question number containing indicators of critical thinking skills of interpretation, analysis, evaluation, and inference.

- *Product Review and Validation*

The review was conducted with a supervisor. The supervisor's evaluation provides feedback and recommendations regarding the developed products and research instruments. Validation was conducted by two lecturers of chemistry education from Unesa and a chemistry teacher from Senior High School 1 Krembung. Validity is

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checked based on content and construct criteria. Content validity criteria include: (a) appropriateness of learning outcomes and learning objectives; (b) appropriateness of content with learning materials; (c) appropriateness with PBL model stages; and (d) appropriateness with critical thinking skills indicators. Construct validity is divided into presentation, language, and graphics. The validity results can be said to be valid if the obtained mode is ≥ 3 with a good category [21]. The following are the validation results obtained from the three validators.

Table 5 Validation Result

Validity	E-Worksheet 1	E-Worksheet 2
Content	3	3
Construct	3	3

Based on the comes about of content validity, mode 3 is gotten consecutively on electronic understudy worksheets 1 and 2 with good categories and pronounced substantial on substance criteria, so these comes about demonstrate that the substance contained within the worksheets is in agreement with the learning targets, learning materials, stages of the PBL demonstrate, and indicators of critical thinking skills. This is in line with Pitasari's research (2023) which states that learning objectives are learning outcomes obtained by students after the learning process for a specific learning topic, so in making learning objectives there are several components that must be met, these components include audience, behavior, condition, and degree (ABCD) [24]. Based on the results of construct validity, mode 3 was obtained with a good category and declared valid on the content criteria, so from these results it proves that the ease of students in using electronic student worksheets (E-worksheet) based on presentation, language and graphics.

D. Implementation

The implementation stage was conducted at Senior High School 1 Krembung on February 19-20, 2025 in class XI-2 as many as 34 students. The implementation phase aims to evaluate the practicality and effectiveness of electronic student worksheets. Practicality is measured through response questionnaires and reinforced by observations of student activities. Meanwhile, effectiveness is determined based on students' critical thinking skills, as assessed through pre-test and post-test results. The results of the practicality and effectiveness of electronic student worksheets are described below.

➢ *Practicality*

Practicality is a criterion that determines the quality of the product developed by looking at the level of ease. Practicality is checked from the learner response questionnaire sheet and activity observation sheet. Response questionnaire data is collected after learning using electronic student worksheets with liveworksheet. The response questionnaire sheet was administered in class XI-2 with 34 students, where the students had to answer a total of 29 statements including 24 positive statements and 5 negative statements. The questionnaire response data can be considered practical if the percentage reaches ≥ 61%, falling into the practical or very practical category [21]. Based on the findings from the student response survey, the overall percentage is 98.17%, so it can be said to be practical to use with a very practical category. Activity observation data analysis was observed by three observers.

The observation sheet developed aspects of learner activity, which included 12 relevant activities and 1 irrelevant activity, where learner activity during learning was observed every 3 minutes when learning activities took place. The implementation of learner activity results is considered effective and supports the practicality of the developed electronic student worksheets if the percentage of relevant learner activity reaches ≥ 61%, falling within the practical or very practical category [21]. The following are the results of student activities during learning at the first and second meetings.

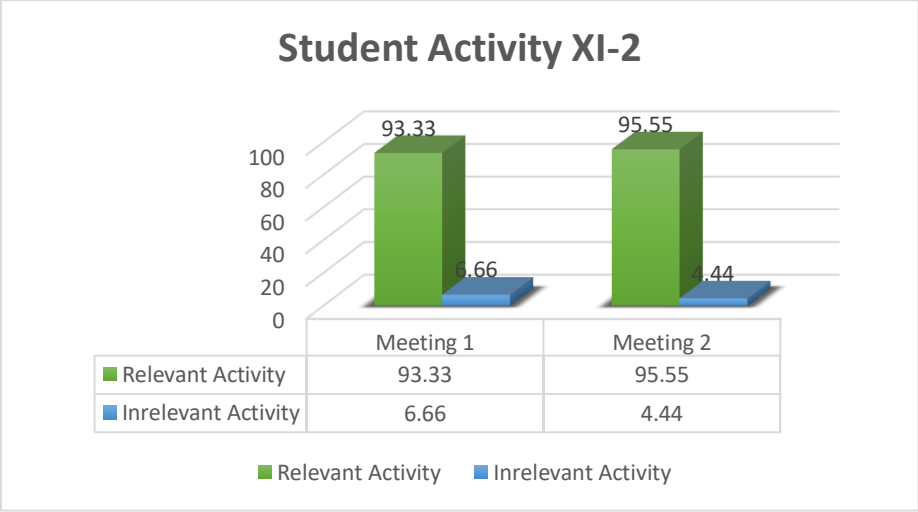

Fig 1 Student Activity Results

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Based on the students' activity results, the first session recorded 93.33% relevant activities and 6.66% irrelevant activities. Meanwhile, the second session received a percentage of relevant activities of 95.55% and a percentage of irrelevant activities of 4.44%. The activity data for the two meetings obtained a proportion of relevant activities exceeds that of irrelevant activities, so that the student activity observation sheet can be properly implemented and support the practicality of the electronic student worksheets developed based on the very practical category. These results are consistent with the research of Firdausichuuriyah & Nasrudin (2017), which states that students' critical thinking skills can be successfully increased if relevant activities obtain a greater percentage than irrelevant activities [25].

➢ *Effectiveness*

Effectiveness is the alignment of expectations with research goals. The effectiveness of a product is measured by the extent to which students achieve the learning objectives set. The effectiveness of electronic student worksheets will be evaluated based on the increase in students' critical thinking skills on the pretest and posttest. The instruments used are pretest and posttest questions with 9 descriptive questions adapted to Facione's 2015 indicators of critical thinking skills such as interpretation, analysis, evaluation, and inference [7]. Based on each component of critical thinking skills, a percentage of ≥ 61% in the effective or very effective category can be declared as successfully trained [21].

The students' pretest and posttest scores were evaluated using the N-gain test to assess the improvement between the two assessments. An increase in critical thinking skills is indicated when the N-gain value is ≥ 0.7 for a high category or ≥ 0.3 for a moderate category [22]. Below are the results of the N-gain score data for each indicator.

Table 6 N-gain Score Results for Each Indicator

Critical Thinking Skills Indicators	Pretest (%)	Postest (%)	N-Gain score	Criteria
Interpretation	40,44%	84,19%	0.74	High
Analysis	37,50%	93,01%	0.87	High
Inference	34,55%	85,29%	0.76	High
Evaluation	29,41%	91,91%	0.88	High

Based on the table above, the results of pretest, posttest and N-gain scores on each indicator obtained an increase between 0.74 to 0.88 in the high category. Thus, it can be concluded that the problem-based learning-oriented electronic student worksheets using liveworksheet is successfully trained and effective in training students' critical thinking skills on the indicators of interpretation, analysis, inference, and evaluation. This is in line with the study conducted by Dewi & Azizah (2019), who found that students' critical thinking skills increased as evidenced by the results of N-gain scores ranging from 0.529 to 0.901 with moderate to high categories [26].

In addition, the data were tested for normality using the Shapiro-Wilk normality test with SPSS. The basis for decision making is seen from the significance value > 0.05, which means that the data is normally distributed. The data below are derived from the Shapiro-Wilk normality test.

Table 7 Shapiro Wilk Normality Test Results

Test of Normality			
	Shapiro-Wilk		
	Statistic	Df	Sig.
PRETEST XI-2	.975	34	.621
POSTEST XI-2	.959	34	.231
*. This is a lower bound of the true significance.			
a. Lilliefors Significance Correction			

Based on the data from the normality test results, the pretest and posttest significance values of class XI-2 were obtained, namely in the pretest of 0.621 and in the posttest of 0.231. Thus, it can be concluded that the pretest and posttest data > 0.05 are normally distributed. Therefore, the next data can be tested with the paired sample t-test. The paired sample t-test test aims to determine the significance of the difference between the pretest and posttest scores. If the sig value obtained is <0.05, then H_0 is rejected and H_1 is accepted, which means that there is a difference in the mean score of students' critical thinking skills. The data below are derived from the results of the Paired Sample t-Test.

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Table 8 Paired Sample T-Test Results

Paired Differences								
				95% Confidence Interval of the Differences				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pretest XI 2-Postest XI 2	-53.265	9.424	1.616	-56.553	-49.977	-32.958	33	0.000

Based on the paired sample t-test results, the significance value for the pretest and posttest scores of class XI-2 is 0.000. Since the significance value 0.000 is less than 0.05, H_0 is rejected, and H_1 is accepted. This indicates a significant difference in the average critical thinking skills of students between the pretest and posttest. Thus, electronic student worksheets using liveworksheet are said to be effective for training students' critical thinking skills on acid-base material.

E. Evaluation

The evaluation phase is the final phase in the development of the ADDIE learning model, which is evaluated at each stage. The following are the evaluation stages in the research.

➢ *Evaluation at the Analysis Stage*

At the problem analysis stage, problems from the learning process were identified, such as students' lack of enthusiasm for acid-base material and the lack of learning media facilities that support the training of critical thinking skills. The results of the analysis are used as an evaluation in the form of determining products or learning media in the form of electronic student worksheets that support learning where oriented Problem Based Learning electronic student worksheets using liveworksheet can train critical thinking skills in acid-base material.

➢ *Evaluation at the Design Stage*

At the design stage, an evaluation is carried out when designing to develop a product. This stage is evaluated in the form of evaluating attractive and relevant images for the electronic student worksheets cover, evaluating the suitability of the electronic student worksheets content with acid-base material, and evaluating the suitability of the learning tools.

➢ *Evaluation in the Development Phase*

In the development phase, the evaluation is based on the results of the review and the results of the content and construct validation by three validators. The purpose of the evaluation in the development stage is to perfect the product that will be used in the next stage, the implementation stage. The results of the evaluation of the three validators on the electronic student worksheets are in the form of suggestions for cover design, less precise sentences on learning objectives, reduction of text on concept maps, addition of observation tables on the electronic student worksheets, and adjustment of PBL phases with indicators of critical thinking skills.

➢ *Evaluation at the Implementation Stage*

At the implementation stage, an evaluation was conducted based on the results of the learner response questionnaire to know the learner response to the developed electronic student worksheets. The learner response data consisted of the students' ease in using the electronic student worksheets with liveworksheet and the students' interest in learning. The results of the response questionnaire amounted to 98.17%, so it can be said to be practical with a very practical category. Furthermore, an evaluation of the results of the pretest and posttest, which measures the critical thinking skills of students based on indicators of interpretation, analysis, inference, and evaluation.

V. CONCLUSION

Based on the findings and discussion of the research regarding the development of a problem-based learning-oriented electronic student worksheet (E-Worksheet) utilizing Liveworksheets to enhance students' critical thinking skills in acid-base topics, the following conclusions can be drawn.

- Validity is confirmed through both validity of the content and the validity of the construct. The validity results in the mode of 3, so the electronic student worksheet (e-worksheet) using liveworksheet is said to be valid with a good category.
- Practicality aspect relates to student activities and responses throughout the learning process. The average percentage of response questionnaire results was 98.17% with a very practical category. Meanwhile, in learner activities, the percentage of relevant activities at the 1st session was 93.33% and at the 2nd session was 95.55% with a very practical category.
- Effectiveness in terms of increasing pretest and posttest critical thinking skills. Based on the information of N-gain on the pretest and posttest of students' basic considering abilities, the comes about of an increment between 0.66 to 1 within the medium and high categories were gotten. At this point, the information from the pretest and posttest comes about were analysed utilizing the normality test utilizing Shapiro Wilk on SPSS, gotten the pretest and posttest significance values of 0.621 and 0.231, so the data was normally distributed because the significance value > 0.05. In extension, using the paired samples T-test, the significance value of the results was 0.000. Based on the T-test results, the significance value obtained was 0.000. Since 0.000 < 0.05, it can be concluded that H0 is rejected, and H1 is accepted. This indicates that there is a significant difference between the

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mean scores of students' critical thinking skills in the pretest and postest.

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