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The Development of Electronic Student Worksheets Based on Problem-Based Learning and Its Impact on Motivation and Problem-Solving Skills

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Abstract: The digital age has transformed education. In the context of chemistry education, particularly in the complex topic of salt hydrolysis, the integration of technology offers innovative solutions to enhance student learning. This study aims to develop and determine the effectiveness of Electronic Student Worksheets (E-LKPD) based on Problem-Based Learning (PBL) in improving students' learning motivation and problem-solving skills in the topic of salt hydrolysis. Through Research and Development (R&D) using the 4D model, the developed E-LKPD in Flipbook format has been validated by material and media experts with high validity values of 0.96 and 0.89 and has received a positive response from students of 80.12%. The research results show that the use of E-LKPD significantly increases students' learning motivation (45%) and problem-solving skills (75%). This indicates that PBL-based E-LKPD is an effective learning media for the topic of salt hydrolysis.

Keywords: Electronic Student Worksheets (E-LKPD); Salt hydrolysis; Problem-based learning (PBL)

Introduction

The rapid development of information technology has significantly transformed the educational landscape. The integration of technology in the learning process is no longer merely complementary but has become an absolute necessity to improve the quality of learning. In the context of chemistry learning, especially for the complex topic of salt hydrolysis, the utilization of technology can be an innovative solution to address the challenges faced by students.

This research aims to develop and evaluate the effectiveness of Electronic Student Worksheets (known as E-LKPD) based on Problem-Based Learning (PBL) in improving students' learning motivation and problem-solving skills on the topic of salt hydrolysis. The choice of PBL is based on its ability to stimulate students to think critically, analyze problems, and seek solutions independently.

Previous studies (Ristiyani & Bahriah, 2016; Atagana& Engida,2014; Boncelet al., 2017; Woldeamanuelet al., 2013; Woldemanuelet al., 2014) have highlighted the challenges students face in understanding the concept of salt hydrolysis. This suggests a need for a more effective and engaging pedagogical approach. E-LKPD based on PBL is anticipated to offer a novel solution to this issue. To address this, this research proposes an innovative learning approach through the development of E-LKPD based on PBL enriched with digital features. The integration of engaging images, videos, and interactive quizzes, as well as the presentation of authentic problems, encourages students to actively participate in the learning process, enhance their motivation, and develop problem-solving skills.

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Given the importance of mastering the concept of salt hydrolysis and the limitations of previous research, this study aims to develop an innovative and interactive E-LKPD based on PBL. By integrating digital features such as videos, simulations, and interactive quizzes, it is expected that this E-LKPD can improve students' academic achievement in understanding the concept of salt hydrolysis, as well as motivate students to learn actively and develop problem-solving skills. The results of this study are expected to contribute to the development of more effective and efficient learning models, especially in junior high school chemistry learning

Method

Research Design

This research aims to develop an Electronic Student Worksheets (E-LKPD) based on Problem-Based Learning (PBL) for the topic of salt hydrolysis. Following Sugiyono (2019), this study employs a Research and Development (R&D) methodology, which is designed to produce and evaluate the effectiveness of a particular product. Sujadi (2003: 164) further explains that research and development, or R&D, is a process or series of steps involved in creating a new product or improving an existing one.

Time and Location

Data collection was conducted from April to June 2023 at SMA 3 N in Yogyakarta, involving 11th-grade science students in the 2022/2023 academic year. SMA 3 N in Yogyakarta was selected due to its alignment with the research criteria and its willingness to participate.

Target/Subjects

The subjects of this study were 11th-grade science students at SMA 3 N in Yogyakarta. A pilot test of the product was conducted with 64 students from two randomly selected 11th-grade science classes at SMA 3 N Yogyakarta. The main field test involved 62 students from four different 11th-grade science classes at SMA 3 N Yogyakarta. These students were randomly selected and grouped based on their understanding levels (high, medium, low). The object of this study was an E-LKPD (Electronic Student Worksheets) based on Problem-Based Learning (PBL) as a teaching material for the topic of salt hydrolysis.

A purposive sampling technique was employed to select the participants. Purposive sampling involves selecting participants based on specific criteria to obtain a sample with the desired characteristics (Sugiyono, 2019). This technique was used because the study focused on all students at SMA 3 N in Yogyakarta. Factors considered in selecting the sample included the school's status, location, classification, and accreditation rating.

Procedure

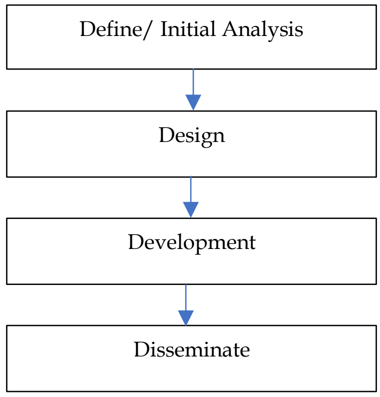

Figure 1. Phase of creating flowcharts for the 4D model

This procedure was carried out using the 4D model, which involves the following stages: 1. **Initial Analysis:** This included a preliminary study, interviews with chemistry teachers to identify their needs and challenges in teaching salt hydrolysis, developing a lesson plan aligned with the 2013 curriculum, and distributing a needs assessment survey to 34 students using Google Forms. 2. **Design:** This stage involved designing lesson plans, motivation questionnaires, pre- and post-tests for problem-solving skills, assessment instruments, and creating the E-LKPD using a combination of Microsoft Word, CorelDraw X7, and Flip PDF Professional 25. 3. **Development:** The developed E-LKPD was then evaluated by experts to ensure its content and media quality. Feedback from the experts was used for the first revision, followed by a limited trial with 64 students from two classes outside the main study. The results of this trial were used to make further revisions. 4. **Dissemination:** As Thiagarajan et al. (2010) explained, the final stage of packaging, diffusion, and adoption is crucial. The dissemination stage involved promoting the developed product to individuals, groups, or systems. The material was packaged selectively to ensure an appropriate format. A field test was conducted with 62 students from four different classes to assess the impact of the E-LKPD on motivation and problem-solving skills. This involved four face-to-face meetings, with online support provided for students who encountered difficulties.

The developed E-LKPD was implemented using a Pretest-Post test Without Control Group design. This design involves a single group that receives the treatment (using the E-LKPD), and changes in student performance are measured by comparing pre-test and post-test scores. (Ersila et al., 2024; Faizin et al., 2024; Gasca-Hurtado et al., 2024; Lestari et al., 2024; Maulida et al., 2024; Setyawan & Masykur, 2022) utilized a Pretest-Posttest Without Control Group design in their research.

Table 1: Pretest Posttest Without Control Group Design

Group	Pretest	Treatment	Posttest
Experiment	O1P1	X	O2P2

Explanation:
O1: Pretest of motivation questionnaire
O2: Posttest of motivation questionnaire
P1: Pretest of problem-solving skills
P2: Posttest of problem-solving skills
X: Treatment with the use of E-LKPD

The independent variable in this study is the use of an E-LKPD based on Problem-Based Learning, while the dependent variables are the increase in students' learning motivation and problem-solving abilities.

Data, Instruments, and Data Collection Techniques

The data collection techniques used in this study include questionnaires, documentation, and interviews. The instruments used were an E-LKPD based on Problem-Based Learning, expert validation sheets, motivation questionnaires, student response questionnaires, and pre- and post-tests for problem-solving skills. This study aims to improve students' learning motivation. Students' learning motivation was analyzed using a motivation questionnaire before and after learning using the PBL-based E-LKPD. Based on the completion of the motivation questionnaire, the significant difference in students' learning motivation can be determined. The motivation questionnaire was developed based on the theories of, the motivation questionnaire consisted of 17 questions covering aspects such as attention, relevance, self-confidence, satisfaction, interest, and concern. (B. D. Jones, 2009; Keller, 1987; T. Jones & Brown, 2011; Visser-Wijnveen et al., 2012)(Pintrich, 2004).

The problem-solving skills test consisted of a pretest given before the treatment and a posttest given after the treatment. Both the pretest and posttest were written tests, each consisting of 10 questions based on problem-solving indicators. The indicators were developed based on Polya's model in (Anugraheni, 2019), which states that there are four stages in problem-solving: understanding the problem, devising a plan, carrying out the plan, and looking back. This is also supported by Sri Wardhani (2010: 33-34) who states that in the problem-solving process, the steps can be carried out sequentially, although sometimes there are steps that do not have to be sequential, especially in difficult problem-solving.

A student response questionnaire was used to obtain data on students' responses to using the PBL-based E-LKPD. The student responses examined included aspects such as content quality, learning interest, appearance, usefulness, and usage.

Data Analysis

This research employs both qualitative and quantitative approaches. The qualitative data in this study consists of suggestions and comments on the validation sheet by validators and student questionnaires regarding the PBL-based E-LKPD. The results of this data analysis are used as material for revising the developed E-LKPD. Meanwhile, the quantitative approach involves expert validation of the content and media, analysis of quality and suitability, student responses, hypothesis pre-test, and hypothesis testing. The results of the score analysis of material experts and media experts use the Aiken's V formula in(An Nabil et al., 2022) . The formula is as follows:

$$V = \frac{\sum S}{n(C-1)} \tag{1}$$

Explanation:
S: Deviation score. This indicates how far a rater's score deviates from the lowest possible score.
r: The score given by a rater for a particular item or aspect.
I0: The lowest possible score. In this case, the lowest score is 1.
C: The highest possible score. In this case, the highest score is 5.
n: The total number of raters.

After calculating the reliability coefficient using Aiken's V, the resulting index values can be categorized as shown in Table 2. This classification helps in interpreting the level of agreement among the raters.

Table 2: Validity Assessment Criteria

Index (Validity)	Category
≤ 0.40	Low
0.41 – 0.80	Moderate
> 0.80	High

A student response questionnaire was administered to collect data on students' perceptions of using E-LKPD to improve their motivation and problem-solving abilities in the context of salt hydrolysis. Both the validation instrument and the student questionnaire utilized a Likert scale.

Prior to hypothesis testing, normality and homogeneity tests were conducted. The Kolmogorov-Smirnov test was employed to assess the normality of the residuals in the regression model. If the data was normally distributed (significance > 0.05), parametric statistics were used. Otherwise, non-parametric statistics were applied. Homogeneity testing, as suggested by Priyanto (2010), was conducted by comparing pretest and posttest scores. Data was considered homogeneous if the significance value was greater than 0.05 in SPSS 25. The usage of SPSS can be referenced in (Cronk, 2024)

To examine the difference in students' motivation and problem-solving abilities before and after the intervention, paired sample t-tests were conducted for normally distributed data, and Wilcoxon signed-rank tests were used for non-normally distributed data. SPSS 25 was used for these analyses.

Effect size tests were performed to quantify the magnitude of the treatment effect. Cohen's d was calculated and interpreted based on the criteria established by (Cohen, 1988)and presented in(Dong et al., 2021) for both paired t-tests and Wilcoxon signed-rank tests (Ratna Yuniarti & Salmi Yuniar Bahri, 2023)

Result and Discussion

The results of the validity test for the PBL-based E-LKPD on the topic of salt hydrolysis, as assessed by both material experts and media experts, are presented in Tables 3 and 4.

Table 3 Content Validity Analysis Results

Assessment Aspect	Validity Index (V)	Category
Content Adequacy	0.93	High
Presentation Adequacy	0.92	High
Language Adequacy	1	High
Alignment with PBL Stages	0.96	High
Problem Solving Skills Integration	1	High
Mean	0.96	High

Table 4 Media Validity Analysis Results

Assessment Aspect	Validity Score (V)	Category
E-LKPD Presentation	0.75	Moderate
Graphics Adequacy	0.95	High
Images, Illustrations, and Videos	1	High
Display Quality	0.75	Moderate
Software Engineering	1	High
Mean	0.89	High

Based on Table 3 and Table 4, the average rating of the E-LKPD by material experts and media experts falls into the high category with a validity score of 0.96 and 0.89 respectively. After undergoing validation and revision based on expert input, the PBL-based E-LKPD on salt hydrolysis has now met the established eligibility criteria. This result is consistent with the findings of (Hidayah et al., 2021) regarding the important aspects of E-LKPD. Thus, this E-LKPD is ready to be used in the learning process, as emphasized by Diani et al (2019) that valid learning materials are those that meet certain standards.

Table 5: Normality test results

Variable	Pretest Significance	Posttest Significance
Learning Motivation	0.200	0.200
Problem-Solving Skills	0.004	0.000

Based on Table 5, the significance value for the learning motivation variable is greater than 0.05, indicating that the data is normally distributed. However, the significance value for the problem-solving skills variable is less than 0.05, suggesting that the data is not normally distributed. Therefore, the hypothesis test was continued using the paired t-test for the learning motivation variable and the Wilcoxon signed-rank test for the problem-solving skills variable.
A test of homogeneity of variances was conducted using Levene's test in SPSS. The results showed a significance value of 0.421, which is greater than 0.05. This indicates that there is homogeneity of variances, or, in other words, the data is homogeneous.

Table 6: Result of Paired T Test

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PretestMotivasi	52.3716	62	7.83285	.99477
	PretestMotivasi	56.1626	62	7.20137	.91458

Based on Table 6, the post-test mean for learning motivation (56.16) was found to be higher compared to the pre-test mean (52.37). The standard deviations for the pre-test and post-test were 7.83 and 7.20, respectively. This indicates that the alternative hypothesis (Ha) is accepted, while the null hypothesis (H0) is rejected. This means there was a significant increase in learning motivation after the implementation of E-LKPD.

To determine the effective contribution of E-LKPD to learning motivation, Cohen's d effect size analysis was conducted. The result was 0.45, which falls into the small category. This suggests that the use of E-LKPD in learning contributed 45% to the increase in learning motivation. It can be concluded that the impact of E-LKPD on students' learning motivation is small or weak. The Cohen's kappa values obtained in this study, like those reported by Fauziah (2019), support the claim that PBL-based learning materials can produce valid and reliable learning outcomes.

Factors such as a non-conducive classroom atmosphere, students' involvement in competitions, limited learning time in both face-to-face and online classes (only 30 minutes per session), and unstable internet connection were identified as major obstacles to achieving effective learning outcomes and contributed to the lower learning motivation. These findings align with Mustakim (2020) and.Auliya (2016) research.

The analysis results are also consistent with previous research by (Mindayula & Sutrisno, 2021) , which found that the use of 3D-Pageflip-based learning media can improve students' learning motivation.

Table 7: Result of Wilcoxon Test

	PosttestTroubleshooting - PretestTroubleshooting
With	-5.874b
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Based on Table 7, the significance value of 0.000 is less than 0.05, therefore the hypothesis is accepted. This indicates that there is a significant difference in students' problem-solving abilities before and after using the E-LKPD media. This suggests that there is a significant improvement in problem-solving skills after the treatment.

The effect size of the Wilcoxon Signed-Rank test is 0.75. This indicates that the effective contribution of the effect size has a large impact on students' problem-solving abilities. The results of the analysis are consistent with previous research findings that have demonstrated the effectiveness of problem-based learning (PBL) worksheets in enhancing students' problem-solving skills (Nafida, et al, 2022). This suggests that the implementation of PBL worksheets in our study can be a valuable tool for improving student outcomes. The results of the evaluation by 62 students regarding the PBL-based E-LKPD on the topic of salt hydrolysis can be seen in Table 8.

Table 8: Student Response Questionnaire Results

Aspect	Score
Content Quality	22.78
Appearance	21.09
Usefulness	87.6
Learning Interest	14.73
Usage	12.78
Average	80.12
Ideal Percentage	80.12%
Category	Good (B)

Student evaluation in Table 8 shows a positive response to the E-LKPD with an average score of 80.12%, indicating that students found the material engaging and effective. This finding aligns with the research conducted by (Türel & Özer Şanal, 2018;Yuliandriati et al., 2019) who discovered that digital textbooks serve as effective learning resources. Moreover, the majority of students indicated a preference for digital materials. In their research, found that the implementation of PBL in learning activity sheets can make learning activities more meaningful. By facing real-world problems, students are encouraged to actively apply their knowledge, improve conceptual understanding, and develop higher-order thinking skills. This research finding is in line with previous findings indicating that PBL is an effective learning model in improving student learning outcomes.

Figure 2. Student Learning

Based on Figure 2, the students appear to be enthusiastic and focused as they listen to the teacher's instructions on how to use the E-LKPD for the upcoming lesson. Their active engagement suggests that they are eager to explore the new learning tool and participate in hands-on activities. This finding is in line with (Denisa & Hakim, 2021) research, which indicated that flip PDFs not only enhance learning enjoyment but also encourage students to learn independently.

Figure 3. Front Cover

Figure 4 Back Cover

Based on Figure 3 and Figure 4, The image above is the front and back cover display of the E-LKPD entitled 'electronic learner worksheets used by students in learning salt hydrolysis. The front cover of the E-LKPD contains the name of the compiler, the university logo, the title of the E-LKPD and there is an illustration depicting salt hydrolysis in daily life as well as a name column for the identity of the student, while the back cover contains the biography of the author.

The table of contents page contains a description of the content page available on the E-LKPD. To make it easier for students to open the page they are going to automatically, E-LKPD is equipped with a clickable table of contents menu button. The inclusion of a table of contents menu button in this E-LKPD aligns with the findings of (Sabrina et al., 2023) study, which demonstrated that interactive features could enhance student motivation. The display of the table of contents button can be seen in the following Figure 5:

Figure 5. Table of contents menu

The competency achievement page contains a list of competencies that need to be achieved by students in learning salt hydrolysis material. On this page there are Basic Competencies (KD), Indicators, and Learning Objectives. The display can be seen in the following Figure 6.

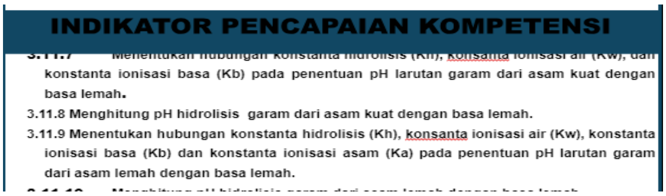

Figure 6. Competency achievement indicator page

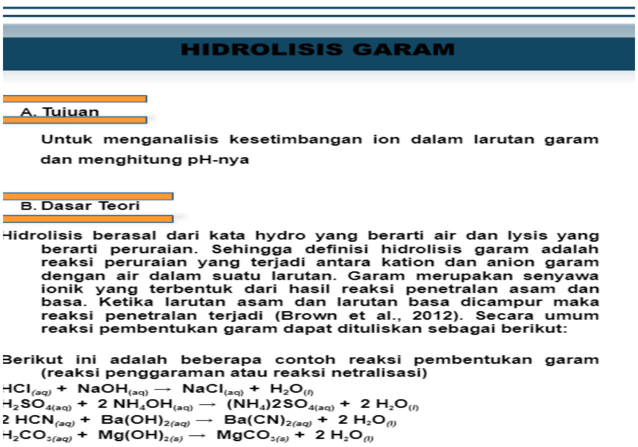

Figure 7. Learning Activity

Based on Figure 7, There are 4 titles of learning activities, namely the concept or basis of the theory and purpose of salt hydrolysis, examples of salt formation reactions, various salt compounds, and problem-solving exercises. The learning process in the PBL model involves a series of systematic steps, namely orientation to the problem, organizing learning, investigation, presentation of results, and reflection and evaluation

Conclusion

Based on the research and development conducted, the E-LKPD on salt hydrolysis demonstrated several positive outcomes. Characteristics of the E-LKPD on salt hydrolysis includes explanations of various real-world applications of salt hydrolysis, providing students with broader knowledge. The E-LKPD is in the form of a Flipbook file with an HTML 5 output, allowing for online access via smartphones, laptops, and computers. This makes it effective for use in teaching salt hydrolysis in chemistry. The PBL-based E-LKPD on salt hydrolysis has been deemed valid and reliable based on assessments by subject matter experts and media experts. It has received a validity rating of 0.96 and 0.89, respectively, falling within the "good" category. Student feedback indicates that the E-LKPD is of good quality, with an average score of 80.12%. This suggests that the PBL-based E-LKPD on salt hydrolysis has a positive contribution and is suitable for use as an alternative teaching material for students. The effectiveness of the PBL-based E-LKPD on salt hydrolysis is further supported by significant improvements in student's learning motivation and problem-solving abilities. There is a significant difference in students' learning motivation before and after the treatment, with an effective contribution of 45%. There is a significant difference in students' problem-solving abilities before and after the treatment, with an effective contribution of 75%.

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Author Contributions
Conceptualized research ideas, methodological designs, data analysis, fundraising, investigative processes, writing original drafts, formulate the research methodology design, management and coordination responsibilities for planning and implementing research activities, D. S. H.; guided, supervised and validated the instruments used in the research, N. A and E. R.

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The authors declare no conflict of interest. The data published in this article, both in data collection, analysis, data interpretation, in writing manuscripts or in the decision to publish research results, there is no conflict of interest with any party.

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