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Developing Problem-Solving Based E-Student Liveworksheet to Improve Students' Critical Thinking in Acid-Base

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Abstract
This study is conducted in response to the low levels of students' critical thinking skills, particularly in interpretation, analysis, inference, and explanation, in the context of acid-base chemistry, as well as the scarcity of digital resources that promote active learning. The objective is to develop a problem-solving-based E-Student Liveworksheet to improve critical thinking skills related to acid-base material. Research and Development (R&D) was employed, following the 4D model (Define, Design, Develop, and Disseminate). The feasibility of the developed worksheet was evaluated using Nieveen's criteria: validity, practicality, and effectiveness. Data were gathered through expert validation forms, student questionnaires, classroom observations, and critical thinking tests. The study involved eleventh-grade students at Gedangan Senior High School. Validation results showed a mode score of 4, indicating high content validity. The practicality score from student responses reached 95%, categorized as "very good." Effectiveness was demonstrated by n-gain scores ranging from 0.50 to 1.00, reflecting moderate to high improvement across all critical thinking indicators. These findings confirm that the liveworksheet is a valid, practical, and effective tool for enhancing students' critical thinking in acid-base learning. In conclusion, the developed digital resource supports the goals of the Independent Curriculum by fostering interactive, contextual, and problem-based learning. This innovation offers valuable potential for broader application in science education and serves as a reference for integrating technology to promote higher-order thinking. Future research is recommended to explore its long-term impact and adaptability across various scientific topics and learning environments.

Keywords: liveworksheet, problem-solving, critical thinking skills, acid-base

INTRODUCTION

Education is a deliberate and structured process that fosters students' potential in spiritual, moral, intellectual, and life skills development. These competencies are essential for both personal growth and societal contribution (Rizkianti et al., 2024). In the era of globalization, education must respond to rapid changes, especially the need to develop students' thinking skills to face 21st-century challenges (Fadliilah & Nasrudin, 2023). In response, Indonesia's Independent Curriculum offers a student-centered approach that supports a meaningful, pressure-free learning environment. It encourages critical thinking and problem-solving skills by engaging students in real-world tasks (Mendikbudristek, 2022). Schools are expected to provide adequate learning tools, such as teaching materials and student worksheets, to support this approach (Rahayu et al., 2022).

One of the chemistry topics that poses significant cognitive challenges for students is acid-base material. This topic encompasses abstract concepts such as acid-base theory, pH calculations, buffer systems, and salt hydrolysis. Field observations at Gedangan Senior High School indicated that 84% of 31 students struggled to comprehend these concepts, particularly those requiring higher-order thinking. Students' difficulties were notably pronounced in subtopics like interpreting pH curves, evaluating buffer solutions, and understanding acid-base reactions, which demand logical reasoning and conceptual understanding.

Critical thinking is essential in learning chemistry, particularly in interpreting phenomena, analyzing data, inferring conclusions, and explaining scientific concepts. Facione (2020) describes critical thinking as consisting of six core skills; however, this study focuses on four indicators relevant to the acid-base topic: interpretation, analysis, inference, and explanation. Pre-research assessments showed that students scored low in all four areas, with two of them classified as very uncritical. These findings suggest that traditional teacher-centered instruction has not adequately nurtured students' critical thinking capacities. To address this gap, the implementation of a problem-solving learning model is deemed suitable. To address this gap, the implementation of a problem-solving learning model is deemed suitable. This model not only supports students in navigating the complexity of acid-base content but also promotes independence and critical engagement with scientific problems (Manikabasagan, 2024). However, for this instructional approach to succeed, it must be supported by learning tools, such as student worksheets, that align with its methodology.

Several recent studies have highlighted the effectiveness of problem-solving-based student worksheets in improving students' critical thinking skills in chemistry education. Sarafina & Nasrudin (2024) developed a guided-inquiry-oriented electronic student worksheet that significantly enhanced students' abilities to interpret, analyze, and infer concepts in acid-base topics. Similarly, Putri & Yonata (2024) reported that a worksheet designed based on problem-based learning principles demonstrated high validity, practicality, and effectiveness in promoting students' critical thinking. Additionally, Nabila & Azizah (2024) confirmed that problem-solving-oriented student worksheets successfully trained students to think critically and solve complex problems in acid-base learning contexts. These findings underscore the importance of integrating pedagogically sound digital learning tools to maximize the impact of problem-solving instructional models.

Unfortunately, the current worksheets in use at Gedangan High School are limited in quality. Many lack illustrations, contextual examples, and opportunities for meaningful student interaction. As a result, students often display low motivation, reduced engagement, and passive learning behavior. To enhance both interactivity and accessibility, this study proposes the use of electronic student worksheets (e-worksheets). Among various platforms, Liveworksheet offers dynamic features like drag-and-drop, instant feedback, audio, and video that allow students to engage directly with content. Unlike passive formats such as PDFs or flipbooks, Liveworksheet facilitates real-time interaction and auto-assessment, making it ideal for flexible, independent learning (Noormiati et al., 2023).

Previous research has demonstrated the positive impact of problem-solving-based e-worksheets in chemistry education, including on topics such as acid-base titration (Marsim et al., 2022), electrolyte solutions (Rosalinda et al., 2023), and salt hydrolysis Puspita & Nasrudin (2025). However, few studies have explored their effectiveness specifically in fostering critical thinking in acid-base learning. Furthermore, earlier implementations often overlooked the interactive potential of digital platforms, limiting student autonomy.

Therefore, this research aims to develop an E-Student Liveworksheet based on Problem Solving for Grade 11 acid-base material to improve students' critical thinking skills. This product is expected to be valid, practical, and effective as a digital learning tool that supports students in mastering complex chemistry concepts and applying them in real-life contexts.

METHOD

This study employed a Research and Development (R&D) approach with the aim of designing an electronic student worksheet using the Liveworksheet platform, integrated with problem-solving strategies to improve students' critical thinking skills on acid-base topics. The development model used is the 4D model, Define, Design, Develop, and Disseminate, as adapted from Thiagarajan (1974).

However, this research was limited to the first three stages (3D): define, design, and develop. This decision was based on several scientific and practical considerations. First, the primary goal of this study is to produce and test a valid, practical, and effective E-Student Liveworksheet based on problem-solving, which aligns with the focus of the develop stage. Second, the disseminate stage is generally applied in large-scale studies for broad product distribution, whereas this research was conducted in a limited scope (on school/class). Third, due to time constraints and limited resources in student-conducted research, it is more feasible to stop at the develop stage. Finally, the dissemination process can be carried out in future research or follow-up studies once the product is ready for wider implementation.

This approach is consistent with Nieveen (2013) view that not all development research must involve all stages of model, espectially when conducted on small scale. In the define phase, a needs analysis was conducted through field observations and literature review. Data were gathered via student questionnaires, teacher interviews, and pre-research assessments at Gedangan Senior High School to identify learning difficulties and students' critical thinking profiles. The literature review at the State University of Surabaya supported the formulation of learning objectives and content scope. The design phase focused on developing research instruments and the prototype of the electronic Liveworksheet. Activities included selecting appropriate media, designing content format and structure, and aligning the worksheet with problem-solving syntax and critical thinking indicators. The develop phase involved expert validation by two chemistry education lecturers and one high school chemistry teacher.

Validation instruments included a review sheet (evaluating content, language, visual design, and alignment with learning models) and a validation questionnaire. Product trials were conducted face-to-face with Grade XI *Matematika dan Ilmu Pengetahuan Alam* (MIPA) students at Gedangan High School, followed by data collection through student response questionnaires and pretest-posttest of critical thinking skills. The research was conducted over four months, from March to June 2025.

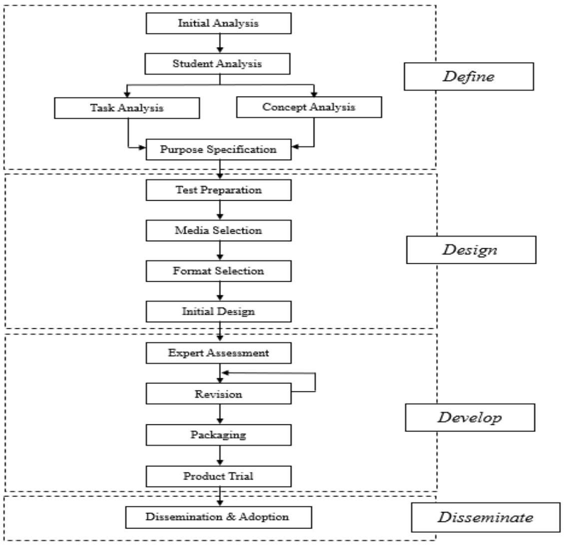


Figure 1. 4D Development Research Design

The focus of this research is the development of an E-Student Liveworksheet based on problem-solving, designed to enhance the critical thinking skills of Grade 11 high school students in the context of acid-base material. The data sources in this study include chemistry education lecturers, Grade 11 chemistry teachers, and Grade 11 science students who have studied acid-base topics. The research instruments consist of: (1) a review sheet for the E-Student Liveworksheet, used to gather input regarding content quality, presentation, language, visual design, alignment with the syntax of the problem-solving learning model, and its relevance to the targeted critical thinking indicators; and (2) a validation questionnaire used to collect expert evaluations. These evaluations were conducted by two chemistry education lecturers and one high school chemistry teacher, focusing on both the media and material aspects of the acid-base content.

Analysis of validation data results using quantitative descriptive methods based on the calculation of assessment score criteria using the following Likert scale.

Table 1. Likert Scale

Category	Value
Very Good	5
Good	4
Fair	3
Bad	2
Very Bad	1

Quantitative descriptive analysis was used. The mode was calculated for each aspect in the validation questionnaire. If the mode score of an aspect is equal to or greater than 4, the aspect is considered valid and does not require revision. If the mode is below 4, it indicates that the aspect needs revision to improve the quality of the developed product.

Practicality analysis was conducted through student response questionnaires supported by activity observations. The questionnaire data were analyzed using the Guttman scale, where a "Yes" response was scored as one and a "No" response as zero.

Table 2. Guttman Scale

Evaluation	Scale Value
Yes	1
No	0

The results of the student response data were analyzed, the percentages obtained were then interpreted in the following response criteria.

Table 3. Response Score Criteria

Criteria	Percentage (%)
Very Good	81-100
Good	61-80
Fair	41-60
Bad	21-40
Very Bad	0-20

If the assessment result percentage is ≥ 61% with a good category, then the E-Student Liveworksheet that is developed has practical criteria.

Practicality analysis was also carried out using a student activity observation sheet. Three observers recorded relevant student activities at three-minute intervals during the learning process. The data were then analyzed based on the average observation results from the three observers using the following formula.

$$Persentase\ (\%) = \frac{\sum Frekuensi\ aktivitas\ peserta\ didik\ yang\ muncul}{\sum Frekuensi\ aktivitas\ keseluruhan}\ x\ 100\%$$

The resulting percentages are subsequently interpreted according to the established scoring criteria. Student activities are considered well-implemented and contribute to the practicality of the E-Student Liveworksheet if the assessment percentage reaches ≥ 61%, falling into the good category. In such a case, the developed Liveworksheet can be categorized as practical (Riduwan, 2019).

The effectiveness was assessed through critical thinking skill tests (pretest and posttest). The results were analyzed using:

$$\%\ keterampilan\ berpikir\ kritis\ = \frac{Skor\ yang\ diperoleh}{Skor\ total}\ X\ 100\%$$

Pretest and posttest results of each individual were analyzed using the n-gain score to calculate the improvement using the following formula.

$$N - gain = \frac{skor\ posttest - skor\ pretest}{skor\ maksimal - skor\ pretest}$$

Based on the calculation results used to determine the increase in students' critical thinking skills before and after using E-Student Liveworksheet. The following are the n-gain score criteria. If the n-gain value experiences an increase in critical thinking skills when ≥ 0.7 with a high category or ≥ 0.3 with a medium category (Riduwan, 2019).

FINDINGS AND DISCUSSION

Findings

This study focused on producing a learning tool in the form of an electronic student worksheet integrated with problem-solving strategies, aimed at fostering students' critical thinking skills within the context of acid-base chemistry. The research adopted a Research and Development (R&D) methodology, specifically applying the 4D model formulated by Thiagarajan (1974), which consists of four main stages: define, design, develop, and disseminate. However, this research was confined to the development phase. Evaluation of the developed learning media referred to the framework established by Nieveen (2013), which emphasizes three essential aspects: validity, practicality, and effectiveness. These were assessed through expert judgment, validation scores, student feedback questionnaires, observation of classroom activities, and analysis of students' performance on critical thinking assessments.

Define Phase

This phase is intended to gather essential information required for developing the problem-solving-based E-Student Liveworksheet aimed at enhancing students' critical thinking skills on acid-base material. It consists of five key steps: initial analysis, learner analysis, task analysis, concept analysis, and the formulation of learning objectives.

Initial Analysis: The initial analysis aims to find out the basic facts experienced by students when learning chemistry. The initial analysis was carried out by observing chemistry learning at Gedangan High School. Observations were made by interviewing chemistry teachers and reviewing the implemented curriculum. Based on the results of teacher interviews, information was obtained that the learning method used was still the lecture method, with a lack of training in critical thinking skills, and the tools used were still in printed form which did not attract students' interest in learning. In addition, observations were also carried out with a pre-research test of critical thinking skills to review the level of critical thinking skills of class 11^{th} MIPA students at Gedangan High School. The results of the pre-research critical thinking skills test can be seen in Table 4 below.

Table 4. Pre-research Results of Critical Thinking Skills Tests

Indicators	Percentage (%)
Interpretation	42,2
Analysis	56,6%
Inference	52,2%
Explanation	45,5

The last, using a pre-research questionnaire distributed to students to find out the experience of learning chemistry on acid-base materials during class. Based on the results of the pre-research questionnaire, it was shown that 81% of students said that the acid-base material was difficult to understand.

Student Analysis: The analysis of students aims to analyze the characteristics of students which include the initial conditions of critical thinking skills, and the difficulties experienced in understanding the material that will be developed in the E-Student Liveworksheet learning media. In his observations it was associated with Piaget's cognitive theory. According to Piaget's cognitive theory, eleventh-grade high school students aged 16-17 should be in the formal operational stage. This stage is the highest stage in human cognitive development. They are able to formulate hypotheses, make logical deductions, and consider various possibilities to solve a problem. However, in practice, not all students develop optimally at this stage. This may be due to a lack of learning stimuli that challenge their abstract and analytical thinking abilities. Therefore, although theoretically students are at a cognitive stage that supports the development of critical thinking skills, learning media are needed that can facilitate these thinking activities more intensively and directed. Therefore, a problem-solving-based E-Student Liveworksheet was developed, designed to train students' critical thinking skills. This problem-solving learning model aligns with Piaget's principle that effective learning must enable students to experience cognitive conflict and actively explore new concepts through direct experience and reflective thinking (Babullah, 2022).

Task Analysis: Task analysis aims to identify or compile tasks that need to be done by students during learning activities. The tasks are listed in the E-Student Liveworksheet that is developed. Things that need to be considered are the suitability of the contents of the E-Student Liveworksheet with learning outcomes, the problem solving model phase, and critical thinking indicators that will be trained (interpretation, analysis, inference, and explanation). The following is a series of electronic student worksheet assignment that were developed.

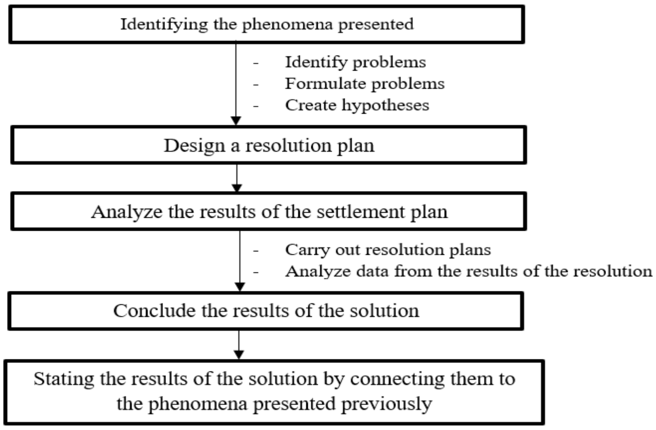


Figure 2. Assesment Design

The design has been adapted to the problem-solving syntax and learning outcomes of acid-base material.

Concept Analysis: Concept analysis aims to determine the concepts of the material that will be learned by students in the acid-base material. According to the learning outcomes of acid-base materials, students are expected to be able to apply the concept of acid-base in everyday life. The concept map diagram for the acid-base material that will be discussed can be seen in Figure 3 below.

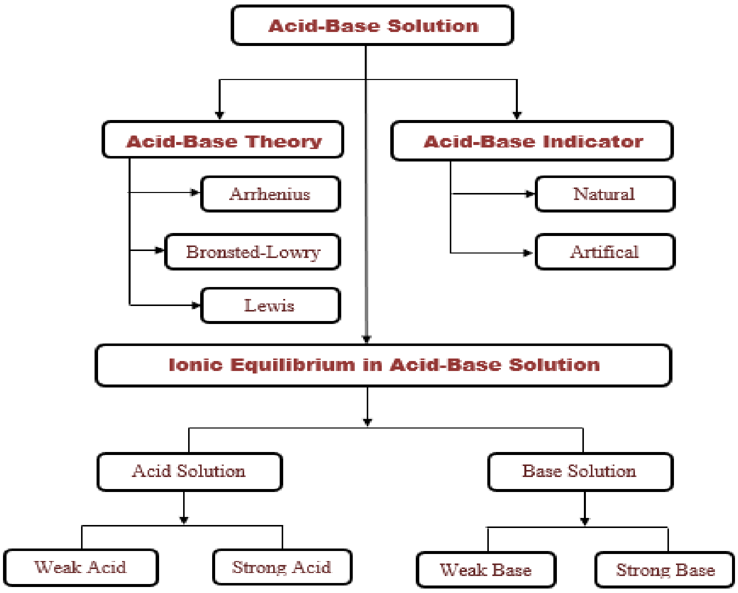


Figure 3. Acid-Base Material Concept Map

Purpose Specification: Objective specifications aim to determine learning objectives that are appropriate for the material to be studied by students. The results obtained from this stage are as follows.

Table 5. Learning Objectives Used

The Meeting	Learning Objectives
1	➢ Through problem-solving activities related to the presented phenomena, students will be able to identify the acid-base concepts of Arrhenius, Bronsted-Lowry, and Lewis ➢ Through problem-solving design, students will be able to analyze the differences between the acid-base concepts of Arrhenius, Bronsted-Lowry, and Lewis ➢ Through problem-solving activities, students will be able to report conclusions and explain data from the analysis of the differences between the acid-base concepts of Arrhenius, Bronsted-Lowry, and Lewis
2	➢ Through problem-solving activities related to the presented phenomena, students will be able to identify the relationship between ionic equilibrium in acid-base solutions and the pH of the solution ➢ Through problem-solving activities, students will be able to analyze the relationship between ionic equilibrium in acid-base solutions and the pH of the solution ➢ Through problem-solving activities, students will be able to report conclusions and explain laboratory data regarding the relationship between ionic equilibrium in acid-base solutions and the pH of the solution
3	➢ Through problem-solving activities related to the presented phenomena, students will be able to identify natural acid-base indicators ➢ Through problem-solving activities, students will be able to analyze natural acid-base indicators ➢ Through problem-solving activities, students will be able to report conclusions and explain laboratory data regarding natural acid-base indicators

Design Phase

The second phase focuses on designing the initial prototype of the media product and related learning tools, based on the results of the analysis conducted during the define stage. This stage includes four main components: the development of assessment instruments, selection of media, determination of format, and the creation of the initial draft of the E-Student Liveworksheet.

Test Preparation: The development of the test instruments is intended to identify the tools used to measure the enhancement of students' critical thinking skills through pretest and posttest assessments. The critical thinking test includes two stages: a pretest administered at the beginning of the learning process to assess students' prior knowledge before utilizing the developed E-Student Liveworksheet, and a posttest conducted after the learning process. The test comprises 12 essay questions aligned with established critical thinking indicators. The interpretation indicator contains questions numbers 1-6. The analysis indicator contains questions numbers 7-8. The inference indicator contains questions 9-10. And the explanation indicator contains questions numbera 11-12.

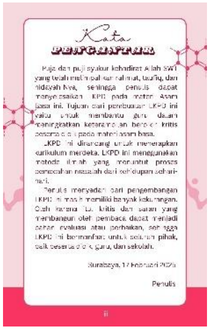
Media Selection: The selection of media aims to align with the needs of students based on previous analysis. The learning media developed is E-Student Liveworksheet using a web live worksheet based on problem solving. The selection of this website is based on its advantages, such as no need to download, no need to log in, no username and password, so students can easily access the link provided by the teacher. The following is the link to the electric student liveworksheet that will be used in this study.

- Main E-Student Liveworksheet: https://www.liveworksheets.com/w/id/chemistry/8048141
- E-Student Liveworksheet 1: https://www.liveworksheets.com/w/id/chemistry/8048157
- E-Student Liveworksheet 2: https://www.liveworksheets.com/w/id/chemistry/8048181
- E-Student Liveworksheet 3: https://www.liveworksheets.com/w/id/chemistry/8048204

Format Selection: The selection of the format is done to facilitate the design of the developed E-Student Liveworksheet. The developed E-Student Liveworksheet format consists of four with one main E-Student Liveworksheet, and three different E-Student Liveworksheet sub-materials of acids and bases. The main E-Student Liveworksheet format consists of a cover, foreword, table of contents, concept map, learning outcomes, a sheet containing a link to the E-Student Liveworksheet sub-material, and a bibliography. While the sub-material E-Student Liveworksheet format consists of a cover, foreword, table of contents, learning objectives and instructions for use, student activities, and a bibliography.

Initial Design: The initial design aims to design the initial design of E-Student Liveworksheet known as draft one. There are three E-Student Liveworksheet's with one main E-Student Liveworksheet. For the first meeting, it discussed the material of acid-base theory, the second meeting discussed ion equilibrium in acid-base solutions, and the third meeting discussed natural indicators of acid-base. The series in E-Student Liveworksheet is adjusted to the problem solving phase and critical thinking indicators.

Table 6. Initial Design of E-Student Liveworksheet

E-Student Livewprksheet	Design
Cover	
Foreword	
Learning Outcomes	
Table of Contents	
Concept Map	

E-Student Livewprksheet	Design
Learning Objectives and Usage Instructions	
Student Activities	
Bibliography	

Development Phase

This stage includes: a) Assessment of the device by experts followed by revision and, b) Product trials to students. E-Student Liveworksheet developed by researchers in the previous stage will be validated by the validator. The explanation of the development stage is as follows:

Expert Assessment: Validation was conducted by two chemistry education lecturers and one high school teacher. As shown in Table 7, the worksheet received a mode score of 4 in both content and construct validity, categorized as good. Although the product met key requirements, validators provided suggestions for further refinement. The outcomes of their assessments are presented in the following Table 7.

Table 7. Validation Results

Aspect	Mode	Criteria
Content Validity	4	Good
Construct Validity	4	Good

Product Trial: The worksheet's practicality and effectiveness were evaluated through student responses and activity observations. The findings from this practicality assessment, derived from both student feedback and activity observation data, are presented in Table 8 and Table 9 below.

Table 8. Response Results

Aspect	Percentage (%)	Category
Critical thinking	87.5	Very Good
Material	100	Very Good
Problem Solving	100	Very Good

Table 9. Activity Observation Results

Aspect	P1	P2	P3
Percentage of Relevant Activities (%)	93	95.1	96.4
Percentage of Irrelevant Activities (%)	6.6	4.4	3.3
Total Percentage (%)	100	100	100

Student responses averaged 95%, categorized as "very good," indicating that the worksheet met practicality standards. Observations showed increasing relevant activity percentages across three meetings, indicating improved engagement and focus, likely due to the worksheet's interactive features and problem-solving orientation.

The effectiveness test of the developed E-Student Liveworksheet can be seen from the results of the critical thinking skills test of students in the form of *pretest* and *posttest.* The following is the data obtained from the results of the product trial in learning using E-Student Liveworksheet based on problem solving.

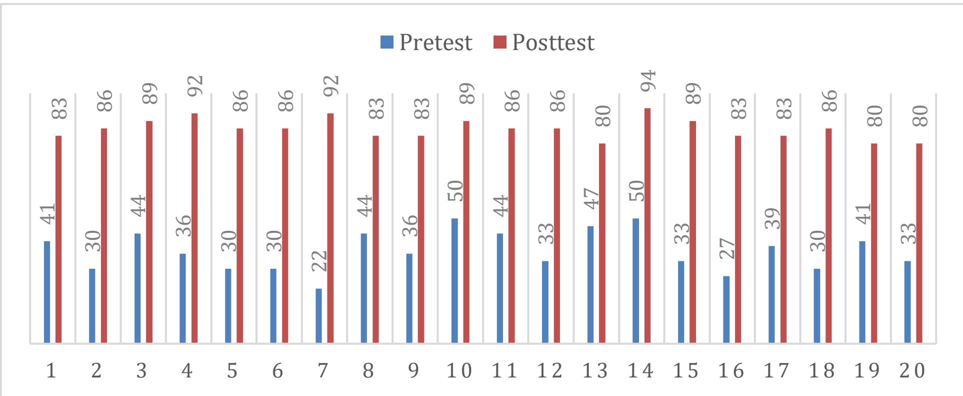


Figure 1. Critical Thinking Skills Test Results

Based on Figure 4, the results of students' pretest and posttest on critical thinking skills show an increase across all indicators. This suggests that the integration of problem-solving-based E-Student Liveworksheet in the learning process had a positive impact. This finding is consistent with the study by Ati & Setiawan (2020), which confirmed that the application of the problem-solving model can enhance students' critical thinking abilities. The improvement in critical thinking skills was further analyzed using the n-gain score. The results showed that for the interpretation indicator, 11 students achieved an n-gain score (g) ≥ 0.7 (high category), while 9 students scored $0.7 > g \geq 0.3$ (medium category). For the analysis indicator, 16 students scored in the high category ($g \geq 0.7$), and 4 students in the medium category ($0.7 > g \geq 0.3$). In the inference indicator, 19 students achieved high n-gain scores ($g \geq 0.7$), and 1 student was in the medium category. For the explanation indicator, 17 students fell into the high category, while 3 students were in the medium category.

The lowest n-gain score was on the interpretation indicator, consistent with research by Cahya et al. (2023), which noted similar challenges in forming hypotheses. Overall, n-gain scores ranged from 0.50 to 1.00 (moderate to high category), indicating that the worksheet effectively improved students' critical thinking skills

Discussion

The development of a problem-solving-based E-Student using Liveworksheet for the topic of acid and base has been proven to be valid, practical, and effective in enhancing students' critical thinking skills. This aligns with the findings of Fadliilah & Nasrudin (2023), who developed a similar digital worksheet using a problem-based approach on salt hydrolysis and reported improvements in students' analytical reasoning and conceptual understanding. The consistent use of structured problem-solving steps encourages students to analyze, interpret, infer, and explain—indicators central to critical thinking.

This study's findings are also supported by the theoretical foundation of Piaget's cognitive development theory as described by Babullah (2022), who emphasized that learners actively construct knowledge when they engage in meaningful problem-solving tasks. The E-LKPD developed in this study provides students with contextual problems, prompting them to go beyond rote memorization and engage in reflective thinking processes. By doing so, the digital worksheet fosters higher-order thinking through active learning experiences.

In line with this, the product was designed using the 4D development model by Thiagarajan (1974), implemented up to the *develop* stage. According to Nieveen (2013), product development in educational research can be adapted to suit the scope and objectives of a study. Since this study focused on producing and testing a prototype in a limited classroom setting, the *disseminate* stage was excluded, and the emphasis was placed on iterative validation and refinement within the *develop* phase.

The ability to think critically is essential for analyzing problems, and it is the responsibility of educators to foster this skill in students. Fundamentally, critical thinking originates from students' natural curiosity and imagination, which they possess from an early age (Syahnia et al., 2024). Moreover, Azizah & Nasrudin (2022) emphasized that integrating critical thinking into instructional media must be accompanied by presentation strategies that challenge students to think logically and systematically. This aligns with the structure of the E-Student Liveworksheet developed in this study, where students are guided through real-world problems requiring the application of scientific data and reasoning.

The effectiveness of Liveworksheet as a platform was also discussed in a study by Noormiati et al. (2023) which concluded that Liveworksheet could improve student independence and learning engagement. This supports the idea that digital tools, when used properly, contribute positively to learners' motivation and cognitive skills. The interactive features such as drag-and-drop, automatic feedback, and time-based assessments within Liveworksheet offer a dynamic and student-centered learning experience.

However, this research is not without limitations. The implementation was confined to a single school setting with a relatively small sample size, thus limiting the generalizability of the findings. Furthermore, this study did not conduct a comparative analysis with other instructional models such as inquiry-based learning or problem-based learning, which could provide a broader understanding of the model's relative effectiveness. Additionally, the digital platform used—Liveworksheet—presented several challenges. As noted by Azizah et al. (2020), many educators still face difficulties integrating digital tools due to limited technological proficiency and lack of training. Liveworksheet, although versatile, requires adequate digital literacy from both teachers and students, and its design features are not yet highly customizable.

These platform-related limitations were also echoed by Nabila & Azizah (2024), who highlighted that the lack of flexibility in content design within certain digital learning platforms can hinder differentiation and adaptation to varied learner needs. Without sufficient support and training, the integration of such tools may result in underutilization, reducing their potential impact on student learning outcomes. This implies the necessity for targeted teacher training programs and technical support systems to ensure optimal implementation.

In summary, this research contributes to the growing body of literature on digital learning media and critical thinking in science education. It provides a practical example of how problem-solving can be translated into an interactive E-Student Liveworksheet format, thus encouraging independent learning and reflective reasoning. Nevertheless, to expand the impact of such innovations, future studies should consider broader implementation, comparative model testing, and ongoing platform development to overcome current limitations and fully realize the potential of digital learning environments.

CONCLUSION

Based on the research findings and discussion, it can be concluded that the problem-solving-based E-Student Liveworksheet developed for acid-base material is valid, practical, and effective in enhancing students' critical thinking skills. This is particularly significant as critical thinking remains a key challenge in science education. The product aligns with curriculum standards while promoting student engagement through interactive, problem-solving-driven activities. This study contributes to educational practice by showing that integrating digital worksheets with structured problem-solving tasks can foster essential thinking skills such as inference, analysis, and explanation—skills often underdeveloped in traditional classroom settings. Additionally, the improvement observed across three implementation sessions highlights the tool's sustainability and adaptability in real classrooms. However, one noted limitation is the need for teacher facilitation during the implementation process. Some students required additional guidance to understand the problem-solving steps effectively. Therefore, it is recommended that future implementations include ongoing teacher support and training to maximize the tool's effectiveness. Future research should also focus on strengthening critical thinking skills further and scaling the application of this tool in diverse educational contexts to broaden its impact.

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