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Implementation of Digital Student Worksheet Based on Problem-Solving to Enhance Students' Critical Thinking Skills and Learning Outcomes on Quantum Numbers and Electron Configuration Materials

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ABSTRACT

In learning chemistry, especially regarding quantum numbers and electron configurations, learning difficulties are still encountered, resulting in low student learning outcomes. One of the factors contributing to this is the use of teaching materials that are less engaging and fail to facilitate students' understanding of concepts effectively. Digital-based student worksheets are an innovative alternative to learning because they can increase students' interaction, understanding of concepts, and critical thinking skills. This research aims to apply problem-solving-based digital student worksheets to improve students' critical thinking skills and learning outcomes. This research employs a quantitative approach with a quasi-experimental design, utilizing a post-test-only control group design. The research sample consisted of 72 class X students at SMA Negeri 5 Banda Aceh. The results showed that the use of digital student worksheets significantly increased students' critical thinking skills (average score of 86.96) and learning outcomes (average score of 85.3) compared to the control group (critical thinking score of 80.20 and learning outcomes of 80.33). Students demonstrated a positive response to the use of digital student worksheets, with an average questionnaire response value of 83.53. The conclusion of this study indicates that the use of digital student worksheets can enhance students' critical thinking skills and learning outcomes. The contribution of community service from this study is manifested in the provision of innovative teaching tools that teachers can adopt to improve collaborative learning and support the development of digital literacy in the school environment.

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Keywords:
digital student worksheet; critical thinking skills; learning; problem-solving

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INTRODUCTION

Education is the main foundation in preparing the younger generation to face the increasingly complex challenges of the times. One of the 21st-century competencies that is crucial for students to possess is critical thinking skills. This ability enables students to analyze information, present arguments, and make rational and logical decisions. In the context of science learning, particularly in chemistry, critical thinking is crucial for grasping abstract concepts and resolving complex scientific problems. However, the reality in the field indicates that students' critical thinking skills remain relatively low. This is due to conventional learning methods that are still prevalent, less interactive and involve minimal student involvement in the learning process. Quantum numbers and electron configurations are topics in chemistry that are known to be complex and abstract. The concepts in this material are difficult to understand if they are only delivered verbally or presented using the lecture method. Therefore, a learning approach is needed that can connect theory with application and

actively involve students in the learning process. One effective approach is a problem-solving approach.

The problem-solving learning method is effective in stimulating students' critical thinking skills in complex problem situations, offering several advantages. It can train students to face and solve problems skilfully and realistically, develop discoveries or ideas, analyze situations, and identify problems with the aim of producing alternatives so that they can make decisions individually or in groups (Chen et al., 2024; Asfar & Nur, 2018) to achieve a target (Koehler & Vilarinho-Pereira, 2023; Jauhar & Makmur, 2017). Balancing the sharpening of students' critical thinking skills is a significant challenge for teachers in the success of the learning process. One solution for teachers to realize learning objectives is to have teaching materials in the form of student worksheets (Aisyah et al., 2020; Ertmer & Koehler, 2018). Student worksheets, as one of the learning media that facilitate students in actively constructing knowledge, have undergone significant transformation in conjunction with technological developments, necessitating the education sector to continue innovating to enhance the quality of education (Hamzah et al., 2023; Irwansyah & Perkasa, 2022). The integration of technology into student worksheets not only enriches the student's learning experience but also opens up new opportunities in the learning process. This is supported by Suryawati (2020), who states that electronic student worksheets are also effective in improving critical thinking skills.

Digital student worksheets were also implemented by Zahroh and Yuliani (2021), Mardhiah et al. (2022), and Salim (2023) and are said to be practical and effective in training students' critical thinking skills. Problem-solving-based electronic student worksheets, developed by Panjaitan et al. (2023) and Asrar et al. (2023), can improve students' problem-solving skills. Learning with the problem-solving method significantly enhances students' learning skills, as they are tasked with finding solutions to the given problems. This approach can also positively influence students' learning outcomes (Bahari, 2024; Ashman et al., 2020; Sutarmi & Suarjana, 2017).

Based on the results of observations and interviews with chemistry teachers at SMA Negeri 5 Banda Aceh, it is evident that teachers have utilized student worksheets; however, student learning outcomes still fall below the learning completion criteria. The student worksheets used have not helped students achieve the desired learning outcomes, particularly in the areas of quantum numbers and electron configuration. The results of the questionnaire and interviews in the case study indicated that students had difficulty understanding the quantum number and electron configuration material because it is abstract. Therefore, the implementation of digital student worksheets that focus on problem-solving is necessary, aiming to enhance critical thinking skills and improve student learning outcomes in the context of quantum numbers and electron configuration material.

METHOD

This research employs a quantitative approach. The type of research employed is experimental research, utilizing quasi-experimental methods (Siedlecki, 2020; Sugiyono, 2019). The design form used is a post-test-only control group. This research was conducted in two classes: the experimental class and the control class. The experimental class received treatment in the form of applying a digital student worksheet based on problem-solving, while the control class used a regular student worksheet. Both classes were only given a final test in the form of a post-test to see differences in improvements in critical thinking skills and student learning outcomes. The sample is part of a representative or representative population (Asrulla et al., 2023; Suriani & Jailani, 2023). The sampling technique in this research was simple random sampling. In this study, the sample was chosen randomly, with classes X-6 and X-4 serving as the research samples. Class X-6 was the experimental class sample, and class X-4 was the control class sample. The determination of experimental class samples and control class samples was carried out by drawing lots, and the names

"X-4" or "X-6" were written on each paper. The first class taken will be the experimental class, and the next class taken will be the control class.

The data collection technique used in this research to measure students' critical thinking skills and learning outcomes is a test. This test consists of questions about quantum numbers and electron configurations. The test was conducted once, specifically at the post-test stage in both classes (control and experimental). The creation of test questions to measure critical thinking skills is prepared in accordance with the question indicators. The question grid is presented in Table 1.

Table 1. Critical Thinking Skills Question Grid

Level of Critical Thinking	Criteria
Identify (I)	Able to state the main idea of the problem being faced
Define (D)	Able to inform what is not used or not needed in solving problems
Enumerate (E)	Mention logical choices and answers
Analysis (A)	Analyze the options to choose the best way and answer
List (L)	State the correct reasons for the method and the best answer chosen
Self-Correct (S)	Thoroughly check the response process again

(Peter, 2012)

A response questionnaire is used to gather students' feedback on their learning experience, utilizing a digital student worksheet that focuses on problem-solving with quantum numbers and electron configuration material. The questionnaire used in this research was administered to 36 students from Class X-6 at SMAN 5 Banda Aceh. The type of questionnaire used in this research is a closed questionnaire, and the scale used is a Likert scale. The student worksheet validation sheet is an instrument used by experts to validate digital student worksheets. Two validators carry out validation activities. The aim is to determine the feasibility of using digital student worksheets as a learning tool for quantum numbers and electron configurations. The documentation in this research consists of a list of names and daily assessments of students. This method is used to obtain data that is relevant and in accordance with the school's research focus.

RESULTS AND DISCUSSION

Research on the application of problem-solving-based digital student worksheets to enhance students' critical thinking skills and learning outcomes in quantum number and electron configuration material was conducted in September and October 2024. The research was conducted in two classes: X IPA 6, an experimental class with 36 students, and X IPA 4, a control class with the same number of students. The research was conducted in three meetings: immediately after treatment in the experimental class (application of a problem-solving digital student worksheet) and the control class (application of a problem-solving student worksheet). At the end of the third meeting, a final test (post-test) was administered to assess students' critical thinking skills and learning outcomes following the learning experience. Based on the research results, data on critical thinking skills and student learning outcomes were obtained. The research results can be described as follows.

The students' critical thinking skills in this study were measured using essay questions that underwent content validation and empirical validation, comprising a total of five items. Critical thinking ability questions are given at the post-test. Next, the post-test results were analyzed using Microsoft Excel to see the average score for each class. The results of the analysis of students' critical thinking skills are briefly presented in Table 2.

Table 2. Analysis of Critical Thinking Ability

Class	The Value of Critical Thinking Skills	Category
	Post-test	
Experiment	86.96	Good
Control	80.27	Enough

The results of the students' critical thinking skills are presented in Table 2, indicating that the critical thinking ability scores of the control and experimental classes differ. The critical thinking ability score after treatment in the experimental class was 86.96, categorized as good (high), and in the control class, it was only 80.20, categorized as sufficient (medium).

The results of this research are supported by the learning process, which shows that using digital student worksheets has a significant effect on students' critical thinking skills and learning outcomes (Annida et al., 2022; Shinta & Sari, 2024). Apart from that, the learning model used can also influence students' thinking skills, whereas the problem-solver learning model has a significant influence on critical thinking skills (Handini et al., 2023; Sasmita et al., 2022). Innovation development can improve students' critical thinking skills because it is designed to practice thinking. A critical thinking process is essential for determining a learning model suitable for students (Kwangmuang et al., 2021; Syamsir et al., 2020). A description of the percentage of critical thinking skills for each indicator in both classes is presented in Figure 1.

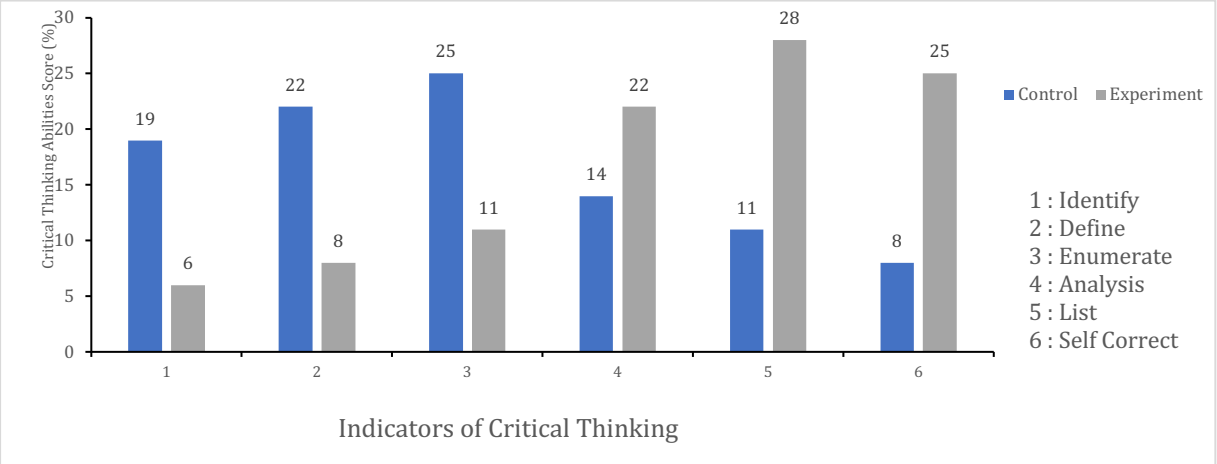

Figure 1. Percentage of Critical Thinking Skills Based on Indicators

This shows that in the control class, students' critical thinking skills are still limited to enumeration, where they are only able to state answers or logical calculation methods but cannot analyze the correct answers. Another thing to note about the experimental class is that it suggests students' critical thinking skills have reached the final stage, where they can state the correct reasons for their answers but have not yet thoroughly reviewed the answer process. The differences in students' critical thinking skills, as observed through the indicators in the control and experimental classes, are attributed to the use of different learning media. This aligns with Zulhelmi (2017), who states that the use of interactive learning media, especially in chemistry lessons, has a significant impact on improving students' critical thinking skills. Learning media in the form of live worksheets also has a very significant effect on students' critical thinking skills and cognitive learning outcomes (Sastrakusumah et al., 2023; Aswanti & Isnaeni, 2023; Hasnunidah et al., 2024; Jauhar & Makmur, 2017).

Student learning outcomes in this study were measured using a digital student worksheet, which was validated for use after content validation, consisting of two materials. Questions about digital student worksheets and traditional student worksheets are addressed during the research. Next, the results of the questions were analyzed using Microsoft Excel to see the average score for each class. The results of the analysis of students' critical thinking skills are briefly presented in Table 3.

Table 3. Analysis of Student Learning Outcomes

Class	Value of Student Learning Outcomes		Average
	Meeting 1	Meeting 2	
Experiment	85.9	84.8	85.3
Control	81.7	78.9	80.33

The student learning outcomes are presented in Table 3, which shows that the learning outcomes scores from the two worksheets in the control and experimental classes differ. The digital student worksheet learning result score, using live worksheets after treatment in the experimental class, was 85.3. In contrast, the control class, which only used regular student worksheets, achieved an average score of 80.33. This suggests that the integration of digital student worksheets with live worksheets has a positive impact on learning outcomes.

The use of digital student worksheets based on live worksheets can improve student learning outcomes by increasing students' cognitive scores (Annida et al., 2022; Paspania & Susilawati, 2024). It can be said that a student worksheet based on live worksheet software is suitable for use as a learning evaluation medium, enabling students to achieve learning outcomes due to their interest in the live worksheet features (Hamidah & Dewi, 2024; Triyani et al., 2024). Using live worksheets with web-based applications can improve student learning outcomes (Prabowo, 2021; Sendag et al., 2015).

The integration of technology in education is significant in improving learning and teaching methodology (Kandemir & Eryilmaz, 2025; Zou et al., 2023). The use of technological tools is significant for improving learning outcomes, as dynamic software applications are not only effective in concept discovery but also crucial in developing problem-solving skills and enhancing reasoning processes, such as students' critical thinking skills (Arzarello et al., 2002; Presmeg et al., 2007). Problem-solving is considered a skill that students develop when faced with a question or situation where the solution is not readily available. In such cases, students should think critically and use specific strategies to find a solution. Therefore, to achieve this, thinking activities are needed (Surif et al., 2012). Someone with advanced problem-solving skills can utilize their knowledge effectively and easily solve the problems they face (Özsoy et al., 2015).

The response questionnaire used in this research was administered only to students in the experimental class. This is because the aim of using the response questionnaire in this research was to determine how students responded to the student worksheet using a live worksheet, whereas it is known that only experimental class students received the student worksheet in this format. The response questionnaire consists of 10 statements, which students have filled in. Researchers use this questionnaire to gather students' responses regarding learning carried out with digital student worksheets using live worksheets.

Based on the analysis results, it was found that students had a very positive attitude towards the student worksheet, which utilized a live worksheet on quantum numbers and electron configurations. This is evident from the average score of students' responses, which is 83.53, indicating a positive attitude. Further explanation regarding the response values obtained by students can be seen based on the value of each response indicator in Table 4.

Table 4. Student Response Questionnaire Assessment

Question Items	Response Value	Category
1	84.1	Good
2	85.9	Good
3	79.7	Good
4	85.4	Good
5	79.2	Good
6	79.8	Good
7	89.1	Good
8	80.9	Good
9	83.7	Good
10	88.2	Good
Average	83.53	Good

Table 4 shows that learning chemistry through digital student worksheets, supplemented with live worksheet media, can improve student learning outcomes. This can also be seen during the learning process, where students are very enthusiastic about answering questions using live worksheets. Based on the results of interviews with randomly selected students, students gave positive responses regarding the use of digital student worksheets via live worksheets. They tended to be more enthusiastic, and it was easier to recall the lessons learned, allowing the critical thinking process to be carried out optimally, as evidenced by the results of their learning.

The use of digital student worksheets can enhance the learning process because they influence the cognitive learning outcomes of students' products and processes. It makes it easy for teachers because they can display teaching materials and assignments in the form of images and videos, which saves time and costs and enables students to complete assignments (Mispa et al., 2022; Rahmadayanti et al., 2022). The live worksheet application can enhance student satisfaction with working on the given questions (Sele, 2022; Wedyastuti, 2023). The use of digital student worksheets, assisted by live worksheets, is effective in enhancing students' understanding skills. Liveworksheet-based student worksheets are effective in increasing students' competence by making them more enthusiastic and motivated to solve the given problems (Zakirman & Aufiana, 2023; Yusuf & Ali, 2022). A digital student worksheet designed to develop critical thinking skills is highly suitable for use and can effectively improve students' critical thinking abilities (Sinaga & Imansyah, 2021; Putra et al., 2023).

CONCLUSION

Based on the research results conducted at SMAN 5 Banda Aceh, it can be concluded that students' critical thinking skills show significant differences. The value of critical thinking skills after being treated in the experimental class is 86.96, which falls in the good (high) category, while in the control class, it is only 80.20, which falls in the sufficient (medium) category. This indicates that in the control class, students' critical thinking skills were still limited to enumerating, whereas in the experimental class, students' critical thinking skills had progressed to the List stage. Student learning results indicate that the learning outcomes from two learning meetings in the control and experimental classes differ. The digital student worksheet learning result score, using live worksheets after treatment in the experimental class, was 85.3. In contrast, the control class, which only used regular student worksheets, achieved an average score of 80.33. This suggests that the integration of digital student worksheets with live worksheets has a positive impact on learning outcomes. Students give a very positive attitude towards the student worksheet, which is carried out using live worksheets on quantum numbers and electron configuration material. This is evident from the average score of

students' responses, which is 83.53, indicating a generally positive attitude. Based on the research results, several suggestions can be made. First, teachers and policymakers are advised to integrate digital-based learning into the curriculum because it has been proven to significantly optimize critical thinking skills and student learning outcomes. Second, for future research, it is suggested that the scope of the research be expanded to gain a deeper understanding. Ultimately, given the significance of technology in learning, all students should have equal access to and benefits from technology without any barriers.

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