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Profile of Students' Problem-Solving Skills on Redox Reactions Using PBL-Based E-Worksheet

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Abstract
This study aims to determine the profile of students' problem-solving skills in redox reaction material assisted by E-Worksheet based on *problem-based learning*. This study is descriptive in nature, using a preliminary research method with data collection techniques carried out using student interview questionnaires, teacher interviews, and preliminary problem-solving skill tests given to students. The data obtained were analyzed descriptively, both qualitatively and quantitatively. This study was conducted on 26 students majoring in mathematics and natural sciences at Semen Gresik High School in Gresik City. The results based on the initial problem-solving skills test showed that the problem-solving skills of the 26 students were still lacking, with a percentage of 74.35% for understanding problems, 51.23% for planning, 51.23% for implementing plans, and 34.61% for evaluation. Based on a questionnaire related to learning media needs filled out by students, it was found that the majority of students (88.5%) still relied on textbooks as their main source of learning. Meanwhile, the use of Student Worksheet was recorded at 46.2%, and only 23.1% had ever used E-Worksheet. This shows that the use of E-Worksheet is still relatively low in the learning process. Chemistry teachers at the school also stated that the *problem-based learning* model had been implemented, but there were still obstacles, one of which was the difficulty in finding real-life problems that were relevant to chemistry material. Therefore, E-Worksheet is needed as a more accessible learning medium to improve students' problem-solving skills in redox reaction material.

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INTRODUCTION

Technological and informational advancements in the 21st century necessitate that students not only understand concepts but also develop advanced thinking abilities, such as solving complex problems. Incorporating technology into education is one strategy aimed at making learning more significant and relevant to worldwide issues (Sihombing et al. , 2023). Within the educational framework, educators serve as guides who leverage information and communication technology to foster critical and active thinking among students during the learning journey (Atika, 2021). These demands require learning approaches that not only emphasize conceptual understanding but also actively train students' problem-solving abilities.

In this regard, the application of the Merdeka Curriculum stresses the importance of profound learning aimed at enhancing student skills, especially in critical thinking and problem-solving. Education should focus not only on grasping concepts but also on connecting knowledge to practical, real-world situations (Menteri Pendidikan Dasar dan Menengah, 2025).

Problem-solving skills are the ability of students to recognize a problem and solve it appropriately based on valid data and information so that accurate conclusions can be drawn (Wardani, 2020). This skill is one of the essential competencies in science learning, including chemistry. Therefore, problem-solving skills need to be continuously trained in learning activities, as through this process students can express ideas and apply their knowledge in everyday life (Nuralifah & Hidayah, 2021). However, in the practice of chemistry learning, students' problem-solving skills are still not optimally developed. Chemistry learning tends to focus on mastering concepts and calculations, causing students to experience difficulties in solving problems that require analysis and application of concepts (Rohayah, 2022).

This is even more apparent in reduction and oxidation (redox) reactions, which are abstract and complex, such as electron transfer and oxidation numbers that cannot be observed directly (Rohayah, 2022). As a result, students often have difficulty understanding concepts and relating them to real-life applications, making learning less meaningful. This condition is also supported by a recent systematic literature review, which reported that students' problem-solving skills in chemistry remain relatively low across various topics, including reaction rate, acid-base titration, chemical equilibrium, and salt hydrolysis. Students were found to experience difficulties in connecting concepts with contextual problems and evaluating their solutions (Miterianifa et al., 2025).

These findings indicate that the issue of problem-solving skills in chemistry learning is widespread and requires innovative instructional strategies. One of the efforts that can be made to support the development of students' problem-solving skills is through the use of appropriate teaching materials. One of the teaching materials commonly used in chemistry learning is the Student Worksheet. The Student Worksheet serves as a means to help students carry out learning activities in a directed manner in accordance with the learning objectives to be achieved (Gusyanti & Sujarwo, 2021). Through Student Worksheet, students can be actively involved in the learning process, understand learning concepts, and practice skills in managing and completing learning tasks independently. In addition, the Student Worksheet also serves as a guide for teachers in organizing learning activities to be more systematic and structured (Nestiadi et al., 2024).

However, the use of printed the Student Worksheet still has several limitations. Printed the Student Worksheet cannot display dynamic visualizations of processes, cannot present videos or animations, and has limited interactivity (Harefa et al., 2022). These limitations pose obstacles in chemistry learning, which requires visual representations to explain abstract concepts, including reduction and oxidation reactions.

Advances in educational technology have driven the need for more interactive and flexible teaching materials. One alternative that can be used is the Electronic Student Worksheet (E-Worksheet). E-Worksheet allows for the integration of various learning media, such as text, images, videos, and interactive activities, thereby increasing student engagement in the learning process (Rohmaya et al., 2023). This digital format also enables more interactive, flexible, and student-centered learning experiences (Anisa et al., 2024). Previous studies also indicate that E-Worksheet can help students understand abstract chemistry concepts through the integration of visualizations, simulations, and interactive activities, making learning more meaningful and engaging. Through E-Worksheet, students also have the opportunity to learn more independently with faster and more varied feedback.

On the other hand, the results of research by Hidayatulloh et al. (2020) show that problem-solving skills are in the moderate category, with the lowest indicator in the ability to plan alternative solutions to problems. This condition indicates the need for learning innovations that provide problem-based learning experiences and train students to think systematically.

In line with these findings, based on preliminary research at Semen Gresik High School, most students consider redox reaction material to be uninteresting and have difficulty understanding its application in everyday life. In addition, the use of digital teaching materials such as E-Worksheet is still relatively low, even though problem-based learning has begun to be implemented. This shows that there is a need for teaching materials that can facilitate problem-based learning more effectively.

One alternative that can be used is the implementation of the Problem-Based Learning (PBL) model supported by E-Worksheet. PBL is a learning model that engages students in facing authentic problems with the expectation that they can construct knowledge independently, develop learning autonomy, and build self-confidence.

This model encourages students to identify problems, search for relevant information, analyze data, draw conclusions, and propose solutions (Puspita & Hidayah, 2025).

Furthermore, PBL presents contextual problems that promote knowledge construction, inquiry skills, and higher-order thinking abilities (Masitha et al., 2024). The integration of E-Worksheet allows learning activities to become more interactive and flexible, thus effectively supporting the implementation of problem-based learning (Fadhila, 2022). However, studies that specifically explore students' initial problem-solving skill profiles in redox reaction topics as a foundation for designing PBL-based E-Worksheet are still limited. Most previous research has focused either on improving learning outcomes through PBL or on developing digital worksheets, without emphasizing the diagnostic analysis of students' problem-solving profiles in abstract chemistry topics.

Redox reactions are conceptually abstract and cognitively demanding, yet digital teaching materials that systematically integrate contextual problem scenarios with structured digital guidance remain underexplor-ed. Therefore, this preliminary study is urgent to provide empirical data that can serve as a basis for developing more targeted and effective PBL-based E-Worksheet in chemistry learning. Therefore, this study aims to identify the initial profile of students' problem-solving skills in redox reactions as a foundation for developing PBL-based E-Worksheet that is aligned with students' actual learning needs.

METHOD

This research aims to determine the percentage of students' problem-solving skills. The study involved 26 twelfth-grade students at Semen Gresik High School who had previously learned redox reaction material. The participants were selected using purposive sampling, considering that these students had completed instruction on redox concepts and were therefore able to demonstrate their problem-solving skills related to the topic. Data collection was conducted with students who were available at the time. Data were collected through teacher interviews, student questionnaires, and problem-solving skill tests. The use of multiple instruments was intended to obtain comprehensive data that align with the research objectives.

Interviews with teachers were conducted to identify learning conditions and challenges in teaching redox material. Student questionnaires were used to explore students' learning experiences and the need for appropriate learning media. Meanwhile, the problem-solving skill test was administered to measure students' initial abilities based on Polya's problem-solving stages.

Data from the problem-solving test were analyzed quantitatively by scoring students' answers according to Polya's four problem-solving steps: understanding the problem, devising a plan, carrying out the plan, and reviewing the solution. The instrument consisted of three essay questions representing five indicators, as shown in Table 1.

Table 1. Outline of the Problem-Solving Skills Instrument

No.	Problem Solving Indicators	Question Number
1	Understanding the problem	1
2	Planning the solution	2
3	Solving problems	3a & 3b
4	Reviewing the solution	3c & 3d

The test results were used to determine the level of achievement for each problem-solving skill indicator using the following formula:

$$\text{Percentage (P)} = \frac{\text{score obtained}}{\text{total score}} \times 100\%$$

Data analysis was conducted by calculating the percentage of students' scores for each indicator. The results were then interpreted into several categories, as presented in Table 2.

Table 2. Problem-Solving Ability Categories

Score (%)	Assessment Category
81-100	Excellent
61-80	Good
41-60	Fair
21-40	Poor
0-20	Very Poor

Quantitative data were analyzed using descriptive statistics by calculating the percentage of students' achievement on each problem-solving indicator. The percentage scores were then categorized into five levels (Excellent, Good, Fair, Poor, and Very Poor) based on predetermined score intervals. Meanwhile, qualitative data obtained from students' written responses were analyzed using content analysis to identify patterns of reasoning, common misconceptions, and the depth of students' evaluation processes. The integration of quantitative and qualitative findings provided a comprehensive description of students' initial problem-solving skill profiles and strengthened the validity of the research results.

RESULTS AND DISCUSSION

This research seeks to analyze the problem-solving abilities of students concerning reduction and oxidation (redox) reactions through the use of E-Worksheet-based Problem Based Learning (PBL). The assessment tool utilized is a problem-solving skill examination created based on four key indicators: grasping the issue, devising a solution, executing the plan, and assessing the solution's outcomes. The specifics of the findings are illustrated in Table 3 below:

Table 3. Average Score for Problem-Solving Skills Indicator

No	Indicator	Average	Category
1	Understanding The Problem	74.35%	Good
2	Planning The Solution	51.23%	Fair
3	Solving Problems	51.23%	Fair
4	Performing A Re-Examination	34.61%	Poor
	Total Average	52,86%	Fair

Based on the analysis of students' answers, problem-solving skills were categorized as excellent, good, fair, poor, and very poor. The results show that most students are in the adequate category, while those in the excellent category are still relatively few. This distribution indicates that students' problem-solving skills have not developed optimally, especially in indicators that require higher-order thinking skills. In addition, the results of this study show that students' problem-solving skills still need to be strengthened, especially in the aspect of evaluating solutions that have lower scores compared to other indicators.

1. Perhatikanlah gambar berikut!

Sumber: https://bobo.grid.id/read/081983324/yuk-ketahui-bagaimana-proses-karat-yang-bisa-terjadi-pada-besi?page=all

Perhatikan gambar di atas! Jika besi dibiarkan tanpa perlindungan, maka lama-kelamaan akan terbentuk bintik-bintik coklat kemerahan pada permukaannya. Apa yang terjadi pada gambar tersebut? Mengapa hal tersebut bisa terjadi?

tersebut bisa terjadi?
yang terjadi pada gambar adalah korosi karat terjadi
karena terkena air hujan

Figure 1. Questions and Answers for The Problem Comprehension Indicator

On the problem understanding indicator, students' problem-solving skills achieved 74.35%, indicating that most students were able to identify the phenomenon of corrosion in iron and mention common causes, such as exposure to water and environmental conditions. This can be seen in the examples of students' answers in Figure 1. However, students' understanding is still phenomenological and does not yet relate the problem to the scientific concept of redox reactions, particularly the oxidation of iron and electron transfer. This condition shows that students are in the early stages of knowledge construction, where they are able to recognize the symptoms that occur but are not yet able to relate them to scientific concepts accurately, as explained in Piaget's cognitive theory that learning occurs through a gradual process of assimilation and accommodation (Arends, 2012). This finding is in line with Rohayah's (2022) research, which states that students tend to be able to recognize chemical phenomena but still have difficulty relating them to the underlying redox concepts.

2. Perhatikanlah gambar berikut!

Sumber: https://www.istockphoto.com/id/foto/peniti-tua-dan-berkarat-terisolasi-di-atas-putih-gm508300038-85186089

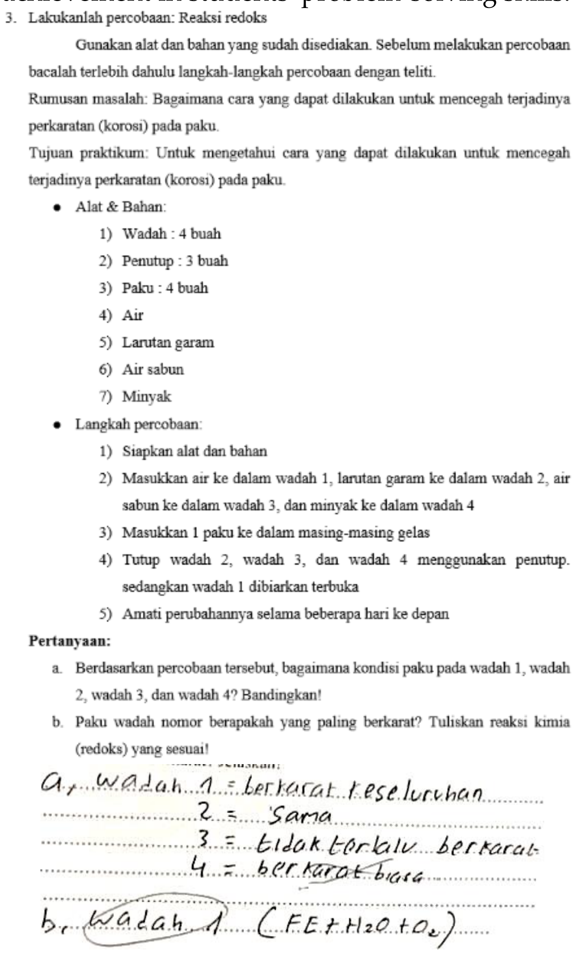
Pada umumnya benda-benda di kehidupan sehari-hari terbuat dari logam, salah satunya adalah besi. Besi merupakan unsur logam dengan kelimpahan yang besar (5%) di alam. Besi digunakan sebagai pondasi konstruksi bangunan, bahan pembuatan pagar hingga peniti. Akan tetapi, penggunaan alat-alat berbahan besi tidak luput dari peristiwa perkaratan atau korosi besi. Contohnya peniti hijab yang sering digunakan akan cepat berkarat. Ada beberapa faktor yang menyebabkan perkaratan, seperti reaksi dengan O_2 dan H_2O. Peniti yang berkarat dapat merusak hijab karena menimbulkan noda merah kecoklatan dan ujung peniti menjadi tumpul.

a. Rumuskanlah pertanyaan yang tepat untuk menggambarkan permasalahan tersebut!
b. Bagaimanakah cara paling tepat untuk pencegahan reaksi oksidasi yang terjadi pada gambar tersebut?
c. Simpulkan dan tuliskan reaksi kimia (redoks) yang sesuai!
Serta buatlah rancangan percobaan untuk penyelesaian permasalahan tersebut!

a. peniti terbuat dari besi (logam) yang terjadi peristiwa perkaratan
b. memberi perlindungan, dengan menyimpan kembali ke tempatnya
c. $H_2O + O_2 \rightarrow 2H_2O$

Figure 2. Questions and Answers on Planning Indicators

In the problem-solving planning indicator, students' problem-solving skills achievement reached 51.23%, indicating that students' ability to formulate problem-solving steps is still relatively low. Students have shown efforts in formulating corrosion prevention measures, such as storing pins in a dry or protected place, as seen in the examples of student answers in Figure 2. However, the plans developed are still general, not systematic, and not based on an accurate understanding of redox reaction concepts, so that the solution steps designed are not yet able to lead to scientific solutions. This low achievement indicates that students still need guidance and social interaction in developing problem-solving strategies, as emphasized in Vygotsky's social constructivism theory regarding the importance of scaffolding in the zone of proximal development (Arends, 2012). These results are in line with the research by Hidayatulloh et al. (2020), which reported that the indicator of planning solutions is the aspect with the lowest achievement in students' problem-solving skills.


3. Lakukanlah percobaan: Reaksi redoks

Gunakan alat dan bahan yang sudah disediakan. Sebelum melakukan percobaan bacalah terlebih dahulu langkah-langkah percobaan dengan teliti.

Rumusan masalah: Bagaimana cara yang dapat dilakukan untuk mencegah terjadinya perkaratan (korosi) pada paku.

Tujuan praktikum: Untuk mengetahui cara yang dapat dilakukan untuk mencegah terjadinya perkaratan (korosi) pada paku.

- Alat & Bahan:
  1) Wadah : 4 buah
  2) Penutup : 3 buah
  3) Paku : 4 buah
  4) Air
  5) Larutan garam
  6) Air sabun
  7) Minyak
- Langkah percobaan:
  1) Siapkan alat dan bahan
  2) Masukkan air ke dalam wadah 1, larutan garam ke dalam wadah 2, air sabun ke dalam wadah 3, dan minyak ke dalam wadah 4
  3) Masukkan 1 paku ke dalam masing-masing gelas
  4) Tutup wadah 2, wadah 3, dan wadah 4 menggunakan penutup. sedangkan wadah 1 dibiarkan terbuka
  5) Amati perubahannya selama beberapa hari ke depan

Pertanyaan:

a. Berdasarkan percobaan tersebut, bagaimana kondisi paku pada wadah 1, wadah 2, wadah 3, dan wadah 4? Bandingkan!

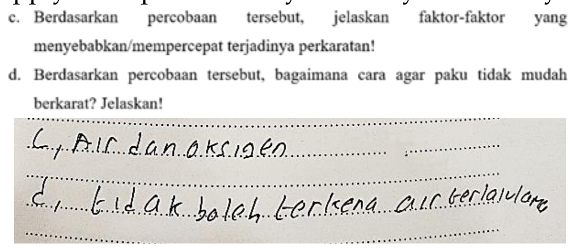
b. Paku wadah nomor berapakah yang paling berkarat? Tuliskan reaksi kimia (redoks) yang sesuai!

a. wadah 1 = berkarat keseluruhan
2 = sama
3 = tidak terlalu berkarat
4 = berkarat biasa

b. wadah 1 (FE + H2O + O2)

Figure 3. Questions and Answers on Indicators for Implementing Plans

In terms of implementing the plan, the students' problem-solving skills achievement was 51.23%, which is classified as adequate. This result shows that some students have been able to apply the planned problem-solving steps, such as calculating oxidation numbers and determining oxidation and reduction processes. However, errors in calculations and inconsistencies in the application of concepts were still found, especially in redox reaction questions involving more than one stage of solution. This condition shows that students are not yet fully able to integrate procedures and concepts as a whole, which according to Bruner's discovery theory requires active involvement and direct experience so that concepts can be constructed in a more meaningful way and remain in memory for a long time (Juliharti et al., 2023). These results are in line with Rohayah's (2022) research, which revealed that students often have difficulty solving chemistry problems due to a lack of ability to apply concepts and analyze data systematically.


c. Berdasarkan percobaan tersebut, jelaskan faktor-faktor yang menyebabkan/mempercepat terjadinya perkaratan!

d. Berdasarkan percobaan tersebut, bagaimana cara agar paku tidak mudah berkarat? Jelaskan!

c. Air dan oksigen

d. tidak boleh terkena air terlalu lama

Figure 4. Evaluation Indicator Questions and Answers

Furthermore, on the evaluation indicator, the achievement of problem-solving skills of students was 34.61%, which was in the poor category. One of the students' answers stated that the factors causing corrosion were water and oxygen, and that nails should not be exposed to water for too long. This answer shows that the students have identified the common factors causing corrosion, but are not yet able to evaluate the results of the experiment in depth by relating the treatment to each container. The low achievement of this indicator shows that students are not yet accustomed to reflecting on and re-evaluating the solutions they have obtained, even though evaluative skills are an important part of meaningful learning as stated by Ausubel, whereby students need to relate new knowledge to their existing cognitive structures (Darmayanti et al., 2023).

This finding is in line with Pratiwi et al. (2022), who stated that problem-solving skills require not only the ability to find solutions but also the ability to think critically and manage problem-solving reflectively so that problems can be solved optimally.

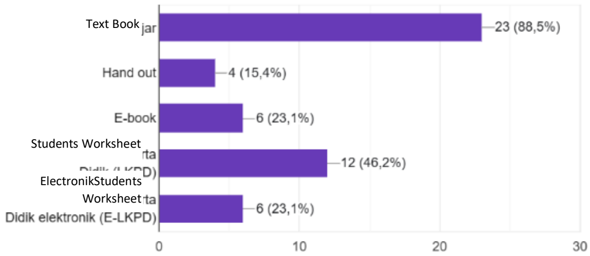


Figure 5. Diagram Showing The Percentage of Learning Resources Used by Students in Chemistry Lessons

These results are supported by preliminary research findings which show that the majority of students (26 answer), namely 88.5%, still rely on textbooks as their main learning resource. The use of Students Worksheet was recorded at 46.2%, while only 23.1% of students had ever used E-Worksheet. These findings indicate that the use of E-Worksheet in the learning process is still relatively low. Chemistry teachers also stated that the *Problem-Based Learning* model had been implemented, but there were still obstacles, one of which was the difficulty in finding contextual problems that were relevant to chemistry material.

These findings are in line with previous studies stating that problem-based learning can train higher-order thinking skills, but requires familiarization and appropriate teaching materials so that students can develop the ability to plan and evaluate problem solving optimally (Rohayah, 2022). These findings are also consistent with recent studies highlighting that students' problem-solving skills in chemistry are still relatively low across various topics.

A systematic literature review by Miterianifa et al. (2025) reported that students often experience difficulties in connecting concepts with contextual problems and in evaluating their solutions, particularly in abstract chemistry materials. In addition, other studies have shown that the use of E-Worksheet can support students in understanding complex concepts through interactive features and structured learning activities that guide them step by step in the problem-solving process (Anisa et al., 2024).

This indicates that integrating digital teaching materials with problem-based learning can provide more meaningful learning experiences and help students develop problem-solving skills more effectively. Thus, PBL-based E-Worksheet can be an effective tool for facilitating the development of students' problem-solving skills, especially in abstract and complex redox reaction material.

Furthermore, the use of PBL-based E-Worksheet has the potential to address the limitations identified in students' problem-solving skills. Through structured problem scenarios, guided inquiry steps, and interactive digital features, E-Worksheet can help students connect abstract redox concepts with real-life situations more effectively. The step-by-step activities provided in E-Worksheet encourage students to understand problems more deeply, plan solutions systematically, carry out appropriate strategies, and reflect on the results. This structured learning support is particularly important for improving the lowest indicators found in this study, especially in planning and evaluating solutions.

In addition to PBL, several studies have applied other approaches to improve problem-solving skills, such as inquiry-based learning, STEM-based learning, and the use of interactive digital media. However, the integration of PBL with E-Worksheet offers a distinctive advantage because it combines contextual problem exposure with structured digital guidance. This combination allows students to actively construct knowledge while receiving continuous support in each stage of problem solving, making learning more meaningful and student-centered.

Compared to recent studies integrating digital learning media and problem-based learning in chemistry education, this study provides a more specific focus on the initial profile of students' problem-solving skills in redox reactions. While previous research generally reported improvements in learning outcomes after implementing digital PBL environments, this study emphasizes the diagnostic stage as a foundation for instructional design. This positioning contributes to a more targeted development of E-Worksheet aligned with students' actual needs.

The findings of this study also provide implications for future educational practice. The integration of PBL-based E-Worksheet is not only relevant for redox reaction material but can also be applied to other abstract topics in chemistry learning. By training students to understand problems, plan strategies, implement solutions, and evaluate results, this approach can support the development of higher-order thinking and problem-solving skills more broadly. Therefore, the use of E-Worksheet can serve as an alternative digital teaching material to support more interactive, contextual, and skill-oriented learning in line with current educational demands.

CONCLUSION

This study revealed that the problem-solving skill profile of students on redox reaction material was in the adequate category with an average score of 52.86%. The indicator of understanding problems achieved the highest score of 74.35%, while the indicator of evaluating problem solving showed the lowest score of 34.61%. Meanwhile, the indicators of planning and implementing problem solving each achieved 51.23%, indicating that students still have difficulty in systematically developing and applying problem-solving strategies. The use of PBL-based E-Worksheet helps facilitate the problem-solving process through the presentation of contextual problems; however, students' skills have not yet developed optimally across all indicators. Therefore, more intensive and continuous problem-based learning is needed so that students' problem-solving skills in redox reaction material can improve more evenly.

This study contributes to chemistry education by providing an initial profile of students' problem-solving skills in redox reactions as a foundation for designing PBL-based E-Worksheet. The findings highlight the need for interactive and contextual learning media that can support students in connecting abstract concepts with real-life phenomena. These results can serve as a reference for teachers in developing more effective problem-based learning strategies and for future research in implementing and testing the effectiveness of E-Worksheet to improve higher-order thinking skills.

Practically, the findings suggest that chemistry teachers should integrate structured digital teaching materials such as PBL-based E-Worksheet to facilitate systematic problem-solving processes, particularly in abstract topics like redox reactions. For future research, experimental studies are recommended to test the effectiveness of the developed E-Worksheet in improving each indicator of problem-solving skills. Further investigations may also explore its implementation in other complex chemistry topics to broaden its applicability

RECOMMENDATION

Based on the findings of this study, it is recommended that teachers strengthen the implementation of Problem-Based Learning by emphasizing the evaluation stage of problem-solving activities, as this indicator showed the lowest achievement. The development of PBL-based E-Worksheet should include more structured reflective questions and scaffolding tasks to help students evaluate solutions using scientific concepts. Future research is also recommended to investigate the effectiveness of PBL-based E-Worksheet through experimental designs and larger sample sizes to examine its impact on improving students' problem-solving skills more comprehensively.

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