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Problem-Based Worksheets Integrated with Corn Cob Adsorbent Experiments in Chemistry Education

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Abstract: *This study aims to analyze students' ability to complete problem-based worksheets, describe students' critical thinking performance, and analyze the free fatty acid (FFA) content of used cooking oil after the addition of corn cob adsorbents. This study employed a quantitative descriptive approach with a pre-experimental One-Shot Case Study design involving 18 fourth-semester Chemistry Education students at UIN Sunan Gunung Djati Bandung. The research instruments consisted of problem-based worksheets, observation sheets, critical thinking assessment sheets, and free fatty acid (FFA) analysis instruments. The results showed that students' worksheet completion performance obtained an average score of 92%, categorized as very good. Students demonstrated critical thinking performance with an average score of 77.72%, categorized as good. The FFA analysis showed that untreated used cooking oil had an FFA content of 0.563%, while used cooking oil treated with corn cob adsorbent and zeolite activated carbon showed FFA values of 0.281% and 0.358%, respectively. These findings describe the application of problem-based worksheets integrated with corn cob adsorbent experiments as a contextual chemistry learning activity that connects analytical chemistry concepts with environmental problems.*

Keywords: *problem-based worksheets, corn cob adsorbent, critical thinking performance, free fatty acid content, chemistry education*

INTRODUCTION

Education plays an essential role in improving human resource quality and supporting national development. The quality of education reflects the ability of a nation to develop independent, knowledgeable, and competitive communities. In Indonesia, educational improvement continues to be emphasized as an effort to strengthen students' competencies in facing global challenges (Tarigan et al., 2024). The development of technology in the Industrial Revolution 4.0 era has created new challenges in education because students are required not only to master knowledge but also to possess skills that enable them to analyze information, solve problems, and adapt to changing

situations. Therefore, 21st-century learning emphasizes the development of the 4C skills, namely critical thinking, creativity, communication, and collaboration(Supena et al., 2021; Zakiah et al., 2020). These competencies can be developed through appropriate learning strategies and instructional materials that actively involve students in the learning process. One learning resource that can support these competencies is the student worksheet, which provides structured activities to guide students in understanding concepts and completing scientific tasks (Putri & Refnaldi, 2021).

Student worksheets are learning tools that can facilitate students in conducting investigations systematically. Through worksheets, students are not only required to memorize concepts but also encouraged to analyze information, interpret data, and construct knowledge based on learning experiences (Izza et al., 2023). In science education, problem-solving ability is an important competency because students need to identify problems, evaluate available information, and determine appropriate solutions through logical and systematic processes. Problem-solving skills represent intellectual activities that involve understanding problems, analyzing conditions, and selecting appropriate solutions based on evidence (Sihotang et al., 2025). Therefore, learning materials that provide opportunities for students to engage in problem-solving activities are needed to support the development of higher-order thinking skills.

Critical thinking is a focused and clear One of the important higher-order thinking skills in science learning is critical thinking. Critical thinking refers to a focused and logical thinking process used in problem solving, decision making, scientific analysis, and evaluation of information. According to Ennis, critical thinking consists of several indicators, including focusing on questions, analyzing arguments, evaluating source credibility, making inferences, identifying assumptions, and determining appropriate decisions (Iqbal et al., 2025). These indicators are relevant to chemistry learning because students are required to analyze experimental phenomena, interpret scientific data, and formulate conclusions based on evidence. Previous studies have shown that worksheets can support the development of critical thinking because they provide opportunities for students to express ideas, analyze phenomena, and evaluate solutions (Sirmayeni et al., 2024).

The development of worksheets based on authentic problems can be implemented through the Problem-Based Learning (PBL) model. PBL is a student-centered learning approach that begins with presenting contextual problems to encourage students to investigate, analyze information, and construct solutions. The implementation of PBL can increase student involvement because learners actively participate in identifying problems, discussing possible solutions, and developing scientific reasoning (Nicholus et al., 2023). Nugraha et al. (2023) explained that PBL supports conceptual understanding through investigation processes, problem solving, and independent learning activities. Similar findings were reported in studies published in the Journal of Innovation in Chemistry Education (JIPK), where problem-based worksheets and learning media were developed to facilitate active learning in chemistry (Nugraha et al., 2023). Gultom and Muchtar (2020) developed an e-worksheet integrated with problem-solving activities and reported that the developed worksheet was feasible and supported student learning outcomes (Gultom & Muchtar, 2020). Barus and Purba (2025) also demonstrated that problem-based worksheets integrated with scientific literacy could facilitate students in solving chemistry problems through structured investigation activities. These findings indicate that problem-based worksheets have potential as learning materials to support meaningful chemistry learning (Barus & Purba, 2025).

In chemistry education, the integration of PBL with experimental activities provides

opportunities for students to connect theoretical concepts with real scientific phenomena. Chemistry learning should not only emphasize conceptual explanations but also involve scientific activities that allow students to observe, investigate, and discover concepts through experiments (Vilela et al., 2025). However, chemistry learning activities are often still dominated by textbook-based explanations, resulting in limited connections between concepts and real-life applications. The presentation of contextual problems through PBL can encourage students to investigate scientific phenomena and develop solutions collaboratively (Arifiani et al., 2025). The PBL learning stages, including problem orientation, organizing students for learning, conducting investigations, developing solutions, and evaluating problem-solving processes, provide a framework for meaningful scientific learning experiences (Nurwidodo et al., 2025). Furthermore, PBL has been reported to support critical thinking development because students are required to analyze problems, collect evidence, and determine solutions based on scientific reasoning (Deshanty et al., 2023; Pratiwi & Wuryandani, 2020). Research in JIPK also reported that PBL-integrated learning media and worksheets contributed to active learning processes and improved students' learning outcomes in chemistry topics (Pardosi et al., 2026; Saragih & Dibyantini, 2024). The integration of experimental activities within problem-based worksheets can strengthen students' ability to apply chemical concepts through scientific investigation and evidence-based reasoning (Siregar & Amdayani, 2024).

One contextual issue that can be integrated into chemistry learning is environmental pollution caused by liquid waste, particularly used cooking oil. Liquid waste originates from various sources, including domestic activities, industrial activities, stormwater, and infiltration processes (Azoma & Amadi, 2024). Used cooking oil is one type of liquid waste that can negatively affect environmental quality when improperly disposed of. Repeatedly heated cooking oil may contain degradation compounds such as free fatty acids, polymers, aldehydes, and other oxidation products that reduce oil quality and may pose health risks (Munawwaroh et al., 2025; Scianò et al., 2025). Therefore, the treatment and regeneration of used cooking oil can become a relevant environmental context for chemistry learning because it involves chemical concepts related to adsorption, material properties, and analytical processes.

Adsorption is one method that can be applied for used cooking oil regeneration because it is relatively simple, economical, and effective for removing undesirable compounds. The adsorption process generally involves the addition of adsorbent materials, mixing, interaction between adsorbent and adsorbate, and filtration processes (Mannu et al., 2023). Previous studies have explored various natural adsorbents derived from agricultural waste, including sugarcane bagasse, wood residues, and coconut shells (Abubakar et al., 2025; Lavrova & Yavorov, 2026; Sultana et al., 2021). These studies demonstrate that agricultural waste materials have potential to be converted into valuable adsorbents. Corn cob is one agricultural waste material with potential application as an adsorbent because it contains carbon-based components and can be converted into activated carbon. Large amounts of corn cob waste are generated from corn processing activities and are often discarded, causing environmental concerns (Castillo-González et al., 2021). Previous studies reported that corn cob adsorbents have suitable characteristics, including carbon content, low moisture content, and high surface area, which contribute to adsorption capacity (Iheanacho et al., 2021; Liu et al., 2021).

Although previous studies have investigated problem-based worksheets, STEM-based learning approaches, and agricultural waste-derived adsorbents separately, the integration of problem-based worksheets with corn cob adsorbent experiments in chemistry education remains limited. Previous studies have mainly focused

on the development of learning media, improvement of learning outcomes, scientific literacy, or conceptual understanding in specific chemistry topics (Barus & Purba, 2025; Gultom & Muchtar, 2020; Siregar & Amdayani, 2024). Meanwhile, the application of problem-based worksheets that incorporate real environmental issues, such as used cooking oil treatment using agricultural waste adsorbents, provides an opportunity to connect chemical concepts with authentic scientific investigations.

Therefore, this study focuses on the application of problem-based worksheets integrated with corn cob adsorbent experiments in analytical chemistry education. The novelty of this study lies in integrating a contextual environmental problem, the utilization of corn cob as a natural adsorbent, and chemical analysis activities within a problem-based worksheet framework. Through this approach, students are guided to investigate used cooking oil quality, analyze adsorption processes, interpret experimental data, and develop scientific reasoning based on evidence. This study aims to describe students' performance in completing problem-based worksheets, analyze students' critical thinking performance, and examine the changes in free fatty acid content of used cooking oil after corn cob adsorbent treatment.

METHODS

This study employed a quantitative descriptive approach using a pre-experimental One-Shot Case Study design. This design was used to describe students' performance after participating in problem-based worksheet activities integrated with corn cob adsorbent experiments in chemistry learning. The design involved one research group receiving the learning activities followed by observation and assessment without a control group or pretest-posttest comparison; therefore, the findings were interpreted descriptively and did not represent causal effects.

The research was conducted in the Chemistry Education Study Program, Faculty of Tarbiyah and Teacher Training, UIN Sunan Gunung Djati Bandung, during the fourth semester of the 2024 academic year. The participants were 18 undergraduate Chemistry Education students enrolled in the Analytical Chemistry Practicum course. The participants were selected using total sampling, as all students enrolled in the practicum participated in the research activities. The students were divided into four groups and conducted learning activities through problem identification, problem-based worksheet completion, laboratory investigation, corn cob adsorbent experiments, data analysis, and presentation of results.

The research instruments consisted of problem-based worksheets, critical thinking performance assessment sheets, observation sheets, and FFA analysis instruments. The worksheets were developed based on the Problem-Based Learning (PBL) stages, including problem orientation, organizing students for learning, investigation activities, developing and presenting results, and analyzing and evaluating the problem-solving process. The worksheets guided students to identify used cooking oil waste problems, investigate adsorption concepts, analyze experimental data, and formulate conclusions based on scientific evidence.

The critical thinking assessment sheet was developed based on Ennis's critical thinking framework, consisting of six indicators: focusing questions, analyzing explanations or arguments, considering source credibility, making and evaluating inferences, identifying assumptions, and determining decisions and conclusions. These indicators were assessed through students' worksheet responses, interpretation of experimental results, and scientific explanations. The observation sheet was used to record students' activities during learning implementation, while FFA analysis instruments were used to determine the free fatty acid content of used cooking oil after adsorption treatment.

The instruments were validated by two Chemistry Education lecturers from UIN

Sunan Gunung Djati Bandung with expertise in chemistry education. The validation assessed content suitability, construct validity, language clarity, and alignment between learning indicators and assessment components. The results showed that validator 1 obtained 90% (very valid) and validator 2 obtained 75% (valid), with an average validation score of 82.5% (very valid). The validated instruments were used as performance assessment tools to describe students' worksheet completion and critical thinking performance. Internal reliability testing was not conducted because the instruments were primarily designed to assess students' performance in contextual learning activities rather than standardized psychometric measurement. Further studies with larger samples are recommended to examine instrument reliability statistically.

The preparation of corn cob adsorbent involved drying, carbonization, grinding, sieving, activation, washing, and drying processes. Corn cobs were dried under sunlight for three days and carbonized using a furnace at 400°C for 15 minutes. The resulting charcoal was ground and sieved using an 80-mesh sieve. The charcoal powder was activated using 2 N KOH solution for 24 hours, filtered, washed with distilled water until neutral pH (pH 7), dried in an oven at 105°C for 3 hours, and cooled in a desiccator before use.

The adsorption experiment was conducted by adding 5 g of activated corn cob adsorbent into 100 mL of used cooking oil (adsorbent-to-oil ratio of 5 g:100 mL). The mixture was stirred and allowed to interact for 2 hours at room temperature before filtration. The treated oil was then analyzed for free fatty acid (FFA) content. The materials used included used cooking oil, corn cob adsorbent, KOH solution, distilled water, phenolphthalein indicator, and standard laboratory reagents. The equipment included analytical balance, furnace, oven, desiccator, mortar and pestle, sieve, burette, Erlenmeyer flask, filtration apparatus, and laboratory glassware.

FFA content was analyzed using an acid-base titration method. A 5 g oil sample was titrated using 0.1 N KOH solution with 1% phenolphthalein (PP) indicator until a stable pink endpoint was obtained. The percentage of FFA was calculated using the following equation:

$$\%FFA = \frac{V\ KOH \times N\ KOH \times BM}{W \times 1000} \times 100\%$$

where V represents the volume of KOH solution used (mL), N represents KOH normality (0.1 N), BM represents fatty acid molecular weight (256 g/mol), and W represents oil sample mass (5 g).

The data consisted of quantitative and qualitative data. Quantitative data included worksheet completion scores, critical thinking performance scores, and FFA values, while qualitative data were obtained from observations during learning activities and laboratory experiments. The percentage score was calculated using (Maulana & Winarno, 2026):

$$Precentage = \frac{obtined\ score}{maximum\ score} \times 100\%$$

Students' critical thinking performance was analyzed descriptively based on Ennis's indicators. FFA values were analyzed descriptively by comparing untreated used cooking oil, corn cob adsorbent-treated oil, and zeolite activated carbon-treated oil. All data were processed using microsoft excel through descriptive statistical analysis. Because this study employed a One-Shot Case Study design without a comparison group, inferential statistical analysis was not applied, and the findings were interpreted as descriptions of students' performance and experimental observations under the applied learning conditions.

RESULT AND DISCUSSION

The learning model applied in this study was Problem-Based Learning (PBL), which was implemented in the fourth-

semester Analytical Chemistry Practicum course. The learning activities were conducted according to the stages of PBL, including problem orientation, organizing students for learning, assisting independent and group investigations, developing and presenting work results, and analyzing and evaluating the problem-solving process. The summary of students' worksheet completion performance at each stage of PBL is presented in Table 1.

Table 1. Average Student Scores at Each Stage of Problem-Based Worksheet Activities

No	Problem-Based Learning Stages	Averages	Interpretation
1	Problem orientation	91,25	**Very Good**
2	Organizing students for learning	95	**Very Good**
3	Assisting independent and group investigations	95	**Very Good**
4	Developing and presenting works of art and exhibiting them	90	**Very Good**
5	Analyzing and evaluating problem-solving processes	88,75	**Very Good**
Overall Average Score		92	**Very Good**

Based on Table 1, the average worksheet completion score for each stage of PBL was 92%, categorized as very good. This result indicates that students were able to complete the activities provided in the problem-based worksheets according to the learning stages. The highest scores were obtained in the stages of organizing students for learning and assisting independent and group investigations, with scores of 95%. These results indicate that students were able to organize learning activities, collaborate with group members, and conduct investigations related to the adsorption experiment of used cooking oil using corn cob adsorbents.

The investigation activities contained in the worksheet required students to analyze experimental procedures, interpret data, and connect chemical concepts with experimental observations. In the problem orientation stage, students obtained a score of 91.25%, indicating that students were able to identify the problems related to used cooking oil waste presented in the worksheet. Meanwhile, the stages of developing and presenting results obtained a score of 90%, and analyzing and evaluating the problem-solving process obtained a score of 88.75%.

The results indicate that problem-based worksheets provided structured activities that guided students during the investigation process. Previous studies reported that problem-based learning activities can facilitate students in analyzing problems, conducting investigations, and developing solutions based on scientific concepts (Madybekova et al., 2026). Furthermore, problem-based worksheets in chemistry learning have been reported to support students' involvement in scientific activities through contextual problems and experimental investigations (Gultom & Muchtar, 2020; Sirmayeni et al., 2024).

Students' critical thinking performance was analyzed based on six indicators adapted from Ennis. The average score of each critical thinking indicator is presented in Table 2.

Table 2. Average scores for each critical thinking indicator

No	Critical Thinking Skills Indicators	Averages	Interpretation
1	Focusing on the question	77,83	Good
2	Asking and answering questions about an explanation or challenge	76,38	Good
3	Considering the credibility of the source	96,11	Very Good
4	Inducing and considering the results of induction	72,5	Good
5	Identifying assumptions	71	Good
6	Making decisions and determining the outcome of deliberations	72,5	Good
Overall Average Score		77,72	Good

Based on Table 2, the average score of students' critical thinking performance was 77.72%, categorized as good. The highest score was obtained in the indicator of considering the credibility of sources, with an average score of 96.11%. This result indicates that students were able to evaluate and select relevant information sources during the investigation process.

The indicators of focusing questions and answering questions about explanations or challenges obtained scores of 77.83% and 76.38%, respectively. These results indicate that students were able to identify problems and provide explanations related to the experimental activities. Meanwhile, the indicators of inducing and considering the results of induction, identifying assumptions, and making decisions obtained lower scores, ranging from 71% to 72.50%.

The lower scores in identifying assumptions and determining conclusions indicate that some students still experienced difficulties in analyzing evidence and formulating decisions based on experimental results. Critical thinking requires students to evaluate information, identify assumptions, and make logical conclusions based on available evidence (Iqbal et al., 2025).

The results describe students' critical thinking performance during the implementation of problem-based worksheets integrated with corn cob adsorbent experiments. Previous research has reported that problem-based learning activities provide opportunities for students to engage in problem identification, investigation, analysis, and scientific reasoning processes (Deshanty et al., 2023; Nicholus et al., 2023).

The next activity analyzed the free fatty acid (FFA) content of used cooking oil after adsorption treatment using different adsorbent materials. The FFA analysis results are presented in Table 3.

Table 3. Results of free fatty acid content determination

Used Cooking Oil Sample	V_1	V_2	$V_{Average}$	Free fatty acid content
Sample A	1,1 mL	1,0 mL	1,01 mL	0,563%
Sample B	0,5 mL	0,6 mL	0,55 mL	0,281%
Sample C	0,7 mL	0,7 mL	0,7 mL	0,358%

The FFA content analysis showed that Sample A (used cooking oil without adsorbent) had an FFA value of 0.563%. Sample B (used cooking oil treated with corn cob adsorbent) showed an FFA value of 0.281%, while Sample C (used cooking oil treated with zeolite activated carbon) showed an FFA value of 0.358%.

According to the Indonesian National Standard (SNI 3741-2002), the maximum allowable free fatty acid content in cooking oil is 0.30% (Ulfindrayani & Ayuni, 2018). Based on this standard,

Sample B showed an FFA value below the recommended limit, while Sample A and Sample C showed FFA values above the recommended limit under the experimental conditions applied.

The differences in FFA values among samples may be related to the interaction between oil components and adsorbent surfaces during the adsorption process. Corn cob adsorbent is derived from lignocellulosic biomass containing carbon compounds that can be converted into adsorbent materials through carbonization and activation processes. The activation process using KOH may contribute to the development of adsorption sites that facilitate interaction with compounds contained in used cooking oil (Iheanacho et al., 2021; Liu et al., 2021).

The comparison between preliminary testing results and student experimental results is presented in Table 4.

Table 4. Summary of preliminary test results compared with student experiments

Sample Variation	Free fatty acid content	
	Preliminary Test	Practicum
Sample A	0,563%	0,51%
Sample B	0,281%	0,25%
Sample C	0,358%	0,34%

Based on Table 4, the students' experimental results showed similar patterns compared with preliminary testing results. Sample A remained the sample with the highest FFA value, while Sample B showed the lowest FFA value among the tested samples. The consistency between preliminary testing and practicum results indicates that students were able to conduct adsorption and titration procedures according to the experimental steps provided in the problem-based worksheets.

The integration of corn cob adsorbent experiments into chemistry learning provides students with direct experience in applying analytical chemistry concepts, including adsorption, titration analysis, and interpretation of chemical data. Through this activity, students were involved in investigating environmental problems and analyzing chemical phenomena using experimental evidence (Fatimah et al., 2025).

CONCLUSION

The implementation of problem-based worksheets integrated with corn cob adsorbent experiments in chemistry education provided a contextual learning activity that connected chemical concepts with used cooking oil waste treatment. Based on the findings, students demonstrated a very good performance in completing problem-based worksheets, with an average score of 92%. The results indicate that students were able to participate in the stages of problem orientation, organizing learning activities, investigation, presentation of results, and evaluation of the problem-solving process.

Students' critical thinking performance based on Ennis's indicators obtained an average score of 77.72%, categorized as good. Students demonstrated the ability to identify problems, analyze information, evaluate sources, and formulate conclusions during problem-based worksheet activities and corn cob adsorbent experiments. The highest performance was observed in considering source credibility, while identifying assumptions remained an aspect that required further development.

The analysis of free fatty acid (FFA) content showed differences among the tested samples under the experimental conditions applied. Used cooking oil without adsorbent

treatment showed an FFA value of 0.563%, while the treatment using corn cob adsorbent and zeolite activated carbon resulted in FFA values of 0.281% and 0.358%, respectively. These findings describe the changes in FFA content after adsorbent treatment and demonstrate the potential application of corn cob-based materials as a contextual example for analytical chemistry experiments.

Overall, the integration of problem-based worksheets with corn cob adsorbent experiments can be considered a meaningful approach for implementing contextual chemistry learning activities. This learning design provides students with opportunities to engage in scientific investigation, analyze chemical phenomena, and relate chemistry concepts to environmental issues. Further studies involving comparative research designs and larger groups of participants are recommended to examine learning outcomes across different instructional conditions.

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