Application of Project-Based Worksheets on the Utilization of Rice Husk Charcoal Adsorbent to Reduce Groundwater Hardness in Develoving Students' Scientific Performance

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ABSTRACT: This study evaluates the effectiveness of project-based worksheets in developing students' scientific performance through practical application of rice husk charcoal adsorbents for groundwater hardness reduction. This is first study integrating project-based worksheets with practical application of rice husk charcoal for water hardness reduction for develoving students' scientific performance in chemistry education. Using a pre-experimental one-shot case study design, 36 twelfth-grade students from SMKN 7 Bandung participated in a six-session practicum involving complexometric titration and adsorption processes. Students' scientific performance was assessed across five project stages using validated rubrics (0-100 scale). Rice husk charcoal adsorbents (0.2g and 0.5g) were tested against groundwater samples, with hardness measured through EDTA titration using established analytical protocols. Results demonstrated consistently high performance across all stages: problem identification (92.1%), project design (91.3%), implementation (89.8%), prototype development (89.8%), product evaluation (95.6%), and finalization (86.7%). Statistical analysis showed significant improvement in students' ability to connect theoretical concepts with practical applications, particularly in understanding complexometric titration mechanisms and adsorption principles. The adsorbent successfully reduced groundwater hardness below WHO standards (500 mg/L), validating both the environmental solution and pedagogical approach. This integrated methodology uniquely combines analytical chemistry education with sustainable environmental remediation, demonstrating measurable enhancement in students' scientific literacy, critical thinking, and problem-solving capabilities through authentic, hands-on learning experiences that address real-world water quality challenges.

Keywords: Rice Husk Charcoal, Water Hardness, Project-Based Worksheet, Complexometric Titration, Scientific Performance.

INTRODUCTION

Project-based learning in chemistry emphasizes the interpretation of science through projects [1] and the implementation of problems into experiences to gain new knowledge [2]. This model focuses on students' ability to process data to produce something useful for society [1]. Worksheets serve as effective learning tools and media for understanding concepts [3] that encompass aspects of attitude, knowledge, and skills in line with learning objectives [4].

Project-based learning with worksheets can develop critical thinking skills, questioning skills, responsibility, independence, and scientific performance [5]. Scientific performance can help students develop problem-solving mindsets [6]. Project-based worksheets serve as a systematic research navigation map and a conceptual framework that connects theory with practice [7] Project-based worksheets systematically enhance students' scientific performance by facilitating comprehensive learning outcomes that encompass academic achievement, critical thinking skills, and scientific attitudes through structured engagement with real-world problems [8].

Project-based learning activities are necessary to optimize students' scientific performance in the laboratory, which can improve their abilities through experimentation Laboratory work aids in understanding complex principles, verifying theories, and providing hands-on experience [7], however, misunderstandings often arise due to misalignment with classroom material, necessitating mastery of scientific performance before applying the scientific method [9]. Students' scientific performance encompasses the measurement of student achievement across various scientific disciplines, typically assessed through classroom performance, practical laboratory skills, and standardized assessments that evaluate both conceptual understanding and application of scientific methods [10]. Therefore, project-based worksheets can be used to help students solve environmental problems such as declining groundwater quality [11].

This research represents the first systematic combination of these two approaches within a structured educational framework. This unique contribution includes the development of a comprehensive project-based worksheet that guides students through the entire scientific process-from problem identification to product evaluation-while addressing a real environmental challenge by using locally available agricultural waste namely rice husk charcoal. This dual-purpose approach not only enhances students' understanding of analytical chemistry concepts such as complexometric titration and adsorption mechanisms, but also develops environmental awareness and practical problem-solving skills through hands-on experimentation with sustainable water treatment solutions. This research innovation goes beyond the traditional laboratory practicum by creating a systematic learning pathway that links theoretical knowledge with practical environmental applications, thus bridging the gap between academic learning and real-world sustainability challenges in chemistry education.

The project-based worksheets facilitate a comprehensive learning experience by integrating theoretical knowledge with practical laboratory applications, especially in water quality assessment where students can systematically explore the topic at hand i.e. complexometric titration method using EDTA to determine groundwater hardness through the formation of stable chelate complexes with calcium and magnesium ions, while simultaneously investigating the adsorption mechanism of rice husk charcoal as a sustainable treatment approach, thereby bridging environmental chemistry principles with practical analytical techniques [12].

Rainwater that seeps into the ground and becomes a source of spring water may contain minerals from limestone rocks such as calcium and magnesium, making it unsuitable for daily use [13]. Water is a vital necessity for humans for drinking and daily activities. Ministry of Health Regulation No. 32 of 2017 sets standards for environmental health quality and water health requirements for hygiene and sanitation purposes, swimming pools, water solutions, and public baths, with a maximum hardness parameter of 500 mg/L. If these requirements are not met, it can be detrimental and pose a health risk.

Hard water can cause health problems such as kidney stones and blood vessel blockages. Hard water also causes skin problems, soap waste, and leaves stains on equipment. Treatment using adsorbents such as zeolite can reduce hardness, but it is not effective for water with turbidity <10 mg/L and hardness >800 mg/L. Natural adsorbents such as rice husk charcoal can be an alternative to reduce hardness levels in water [14].

Indonesia, as a maritime country, produces rice husk waste that has the potential to be used as an alternative adsorbent to replace expensive activated carbon. Rice husks have a composition of lignin (21.44%), cellulose (32.24%), hemicellulose (21.34%), and minerals (15.05%) with a granular structure, good chemical stability, and high mechanical strength, making them suitable for water treatment adsorption processes and provides students with rich opportunities to investigate structure-function relationships in adsorption processes while developing their scientific performance skills. Through project-based worksheets, students can systematically explore how these compositional characteristics into practical water treatment applications, bridging theoretical knowledge with real-world problem-solving [14]. This approach enhances scientific performance by encouraging critical thinking, data analysis, and environmental awareness through sustainable waste utilization while gaining environmental awareness through sustainable waste utilization. Students apply complexometric titration techniques while engaging in authentic investigations, guiding them from hypothesis formation to evidence-based conclusions using locally available resources. [15].

RESEARCH METHODS

Materials and Tools

This study used a pre-experimental method with a one-shot case study design. The sample was using groundwater as the practical material and compared the mass of 0.2 grams and 0.5 grams of rice husk charcoal adsorbent in 150 mL of groundwater at Campus 2 of UIN Sunan Gunung Djati Bandung, because groundwater in Campus 2 of UIN Sunan Gunung Djati Bandung meets the required water hardness criteria.

The students conduct an experiment using the Na_2EDTA secondary standard solution was prepared at 0.01 M concentration and standardized against a 0.01 M_{CaCl_2} primary standard solution using Eriochrome Black T (EBT) as the metallochromic indicator at pH 10.0, maintained using an ammonia-ammonium chloride buffer system. For total hardness determination, 50 mL aliquots of groundwater samples both pre- and post-adsorption were titrated with the standardized EDTA solution, with titration endpoints identified by the distinct color change from wine-red to blue, indicating complete complexation of Ca^{2+} and Mg^{2+} ions. Water hardness was calculated using the formula:

$$\text{Total Hardness (mg CaCO}_3\text{/L)} = \frac{1000}{V_{c.u}} V_{EDTA} \times M_{EDTA} \times 100$$

Explanation:
V_{EDTA} = Volume of EDTA (mL)
M_{EDTA} = Molarity of EDTA solution (mol/L)
$V_{c.u}$ = Sample volume (mL).

For calcium hardness determination, 150 mL water samples were adjusted to pH 12-13 using NaOH solution to precipitate Mg^{2+} as $Mg(OH)_2$, followed by titration with EDTA using murexide indicator, with endpoints marked by color transition from pink to purple. Quality control measures included duplicate analyses for each sample. The mass of 0.2 grams and 0.5 grams of rice husk charcoal adsorbent contact time was adsorbed in 30 minutes with continuous stirring at 150 rpm, and filtration was performed using filter paper to ensure complete separation of adsorbent particles before titration analysis. The research design is shown in Table 1.

TABLE 1. Research Design

Treatment	Observation
X	O

Explanation:
X = Treatment Administration
O = Observation after treatment [16].

The data source for the study on the use of rice husk charcoal adsorbents in groundwater hardness using project-based worksheets was 36 students in the 12th grade of Clinical and Community Pharmacy 1 in the second semester who were taking the Analytical Pharmacy Chemistry Practicum course for 6 sessions, from January 6 to February 17, 2025, with each session lasting 2 hours (2×45 minutes). The research was conducted at SMKN 7 Bandung, located at Jl. Soekarno-Hatta No. 596, RT.007/RW.02, Sekejati, Buahbatu District, Bandung City, West Java 40286.

Method of Quantitative Analysis

The study used quantitative analysis and project-based worksheets as instruments, with data collected through the completion of worksheets on the use of rice husk charcoal adsorbents to reduce groundwater hardness, with the aim of assessing students' scientific performance in the practicum. The data was processed in the following stages:

a. Assigning scores to each point on the worksheet based on the assessment rubric.

TABLE 2. Project-Based Worksheet Assessment Rubric.

Stages of Project-Based Worksheets	Question Number	Score
Problem Identification	1	0 – 3
	2	0 – 3
Create project designs	3	0 – 3
	4	0 – 3
	5	0 – 6
	6	0 – 18
Project Implementation	7	0 – 3
Develope draft/prototype product	8	0 – 3
	9	0 – 3
	10	0 – 18
	11	0 – 3
	12	0 – 3
	13	0 – 3

TABLE 3. The Finalization And Publication Stage Assessment Rubric.

Observed Aspects	Score
Title	0 – 3
Experiment Objective	0 – 3
Theoretical Basis	0 – 3
Results and Discussion	0 – 3
Conclusion	0 – 3
Bibliography	0 – 3

b. Checking and analyzing each answer written by the students.

Student responses on project-based worksheets were analyzed using a structured rubric-based approach. Each answer was evaluated for accuracy, completeness, and alignment with rubric indicators across all project stages. Scores were assigned according to predefined ranges (e.g., 0–3, 0–27), then converted to percentages and categorized using the interpretation scale in Table 4. To enhance reliability, two raters reviewed a sample of responses, and discrepancies were resolved through discussion. In addition to scoring, qualitative notes were recorded to identify common misconceptions and exemplary reasoning.

The assessment rubric employed a structured scoring system with clearly defined criteria across multiple ranges. For the 0-3 range, the scoring criteria were established as follows: a score of 3 indicated the formulation of relevant answers that could be addressed through experimental procedures; a score of 2 represented the creation of somewhat less relevant answers that remained experimentally addressable; a score of 1 denoted the production of answers that were neither relevant nor answerable through experimental results; and a score of 0 indicated no answer formulation. The 0-6 range incorporated two distinct assessment subindicators, each evaluated within the 0-3 framework, while the 0-18 range encompassed six subindicators, with each subindicator similarly assessed using same 0-3 scoring criteria, thereby providing a comprehensive evaluation mechanism that maintained consistency across different assessment scales.

c. Assigning scores to each answer based on the categories.

TABLE 4. Scores assigned to each answer by category.

Score	Categories
67 – 100	High
34 – 66	Medium
0 - 33	Low

d. Adding up the scores.
e. Calculating the scores obtained using the following formula:

$$X = \frac{\sum n}{N} \times 100\%$$

Explanation:
X = Score
Σn = Total student worksheet scores
N = Total question scores
f. Averaging the worksheet scores obtained.
g. Compiling scores based on the criteria presented [17].

TABLE 5. Interpretation of Project-Based Worksheets

No.	Category Presentation (%)	Interpretation
1.	80 – 100	Very Good
2.	70 – 79	Good
3.	60 – 69	Fair
4.	50 – 59	Deficient
5.	≤ 49	Very Deficient

RESULT AND DISCUSSION

Students' scientific performance refers to the systematic evaluation of students' knowledge and skill attainment in scientific disciplines, which demonstrates a strong positive correlation with the structured stages of project-based worksheets that progressively enhance conceptual comprehension, practical application skills, and academic achievement through sequential learning activities. The stages of project-based worksheet development are divided into five stages, namely 1) Problem Identification; 2) Create project designs; 3) Project Implementation; 4) Develope draft/prototype product; and 5) Finalization and publication [18]

Problem Identification

The practicum began with students reading the learning objectives and discourse in the worksheet. The problem identification stage served as an introduction, where students learned about the problem of using rice husk charcoal adsorbents to reduce soil water hardness and its solution. This was followed by problem formulation and hypothesis development as initial assumptions that provided clear direction for the experiment. The results of the student worksheet assessment at the problem identification stage are shown in Table 6.

TABLE 6. Assessment Results at the Problem Identification Stage

Observed Aspects	Category	Number of Students	Score	Interpretation
Identifying the problem based on the discourse presented	High	28	92.6	Very Good
	Medium	8		
	Low	0		
Formulate hypotheses	High	27	91.7	Very Good
	Medium	9		
	Low	0		
Average			**92.1**	**Very Good**

Based on Table 6, the aspect of identifying problems is the aspect with the highest score in the problem identification stage, showing a very good results with an average of 92.6. A total of 28 students were in the high category and 8 students in the medium category. The majority of students were able to analyze complexometric titration discourse and the reduction of groundwater hardness, as well as identify the main problems for scientific research.

Students in the moderate category faced three challenges, which are difficulty in identifying important variables in complexometric titration and the adsorption process due to insufficient understanding of water hardness and the principles of EDTA titration, resulting in problem formulation that was either too general or too specific, and difficulty in connecting the concept of complexometric titration with the adsorption process, as they did not understand that the adsorbent binds the ions causing hardness before the titration measurement.

The aspect of hypothesis formulation is the lowest aspect in the problem identification stage, but it still shows excellent results with an average of 91.7. A total of 27 students were in the high category and 9 students in the medium category. The majority of students were able to formulate hypotheses based on scientific concepts of complexometric titration and water hardness reduction using rice husk charcoal adsorbents.

Nine students in the moderate category faced three difficulties: they were unable to develop specific hypotheses, had difficulty linking hypotheses to theoretical foundations, and tended to formulate descriptive hypotheses without predictive elements. Effective hypotheses should include predictions about relationships between variables, such as “The greater the mass of adsorbent, the greater the reduction in water hardness measured through complexometric titration.”

Overall, the assessment of the problem identification worksheet showed very good results with an average score of 92.1. This proves that the learning process successfully developed students' scientific thinking skills in identifying problems and formulating hypotheses. This success is supported by an approach that connects analytical chemistry concepts with everyday problems, in line with [19] perspective that problem-solving skills are crucial for the development of scientific process skills.

Create Project Design

In the project design stage, students develop a plan for the project to be carried out. The questions in this stage help students formulate the objectives of the experiment, develop a theoretical basis, determine the tools and materials, and develop the experimental procedure. The results of the worksheet assessment are shown in Table 7.

TABLE 7. Assessment results in the creating of project design stage.

Observed Aspects	Category	Number of Students	Score	Interpretation
creating experimental objectives	High	36		Very Good
	Medium	0	100	
	Low	0		
Developing experimental principles	High	25		
	Medium	10	89.8	Very Good
	Low	1		
Determining tools and materials	High	29		
	Medium	7	93.5	Very Good
	Low	0		
Creating experimental procedures	High	26		
	Medium	10	82.9	Very Good
	Low	0		
Average			**91.3**	**Very Good**

Based on Table 7, in the creating of project design stage, the aspect of creating experimental objectives had the highest score, while the aspect of creating experimental procedures had the lowest score, resulting in an average score of 91.3, which is interpreted as very good.

The aspect of creating experimental objectives has a value of 100, which is interpreted as very good. All students are in the high category, indicating that all students are able to articulate experimental objectives clearly, specifically, and measurably related to complexometric titration for reducing water hardness using rice husk charcoal adsorbents. This achievement reflects a systematic understanding of the importance of research. Effective experimental objectives include determining the effectiveness of the adsorbent in reducing hardness and comparing the mass of the adsorbent using the complexometric titration method.

The aspect of creating experimental procedures is the aspect with the lowest score in the creating of project design stage, with a score of 82.9, but it is still interpreted as very good. A total of 26 students were in the high category and 10 students in the medium category, with no students in the low category, indicating variation in ability in compiling experimental procedures with systematic flowcharts.

Students in the medium category for the creation of experimental procedures faced difficulties in systematically organizing steps, which included unclear separation of the adsorption and complexometric titration process stages, as well as explaining important parameters such as contact time in adsorption, EDTA solution volume, or titration endpoint criteria.

The overall assessment of the worksheet for the project design stage achieved an very good result with an average of 91.3. This indicates that the learning process successfully developed students' ability to design experiments. This ability is important in project-based learning. According to [20] the application of project-based worksheets can enhance students' scientific performance during the draft/prototype stage. Therefore, improvements are still needed, such as strengthening students' understanding of fundamental concepts like water hardness, complexometric titration, and the adsorption process, as enhancing their ability to connect various chemical concepts.

Project Implementation

During the project implementation phase, students conducted a practical experiment on reducing groundwater hardness using rice husk charcoal adsorbents in accordance with the procedures they had previously designed. Since the experimental procedures were quite complex and required a significant amount of time, the implementation was divided into four consecutive weeks, conducted every Monday for a duration of two class hours.

In the first week, students began doing project-based worksheets and conducted two experiments. First, the standardization of the Na_2EDTA secondary standard solution using a 0.01M $CaCl_2$ primary solution. Second, inlet titration or complexometric titration of total groundwater hardness before adsorption using rice husk charcoal adsorbent. This activity can be seen in Figure 1 and figure 2.

Figure 1. Students work on the project-based worksheet

Figure 2. Student activities in experiments one and two, which involved measuring solutions.

In the second week, students conducted complexometric titration experiments to determine the calcium content in the hardness of untreated groundwater. Subsequently, students adsorbed the hard water using rice husk charcoal adsorbents in quantities of 0.2 grams and 0.5 grams, each adsorbed for 30 minutes. This activity can be seen in Figure 3.

Figure 3. Student activities in experiments three and four, which involved performing complexometric titration to determine the Ca content.

In the third week, students performed outlet titration or complexometric titration of soil water hardness after adsorption using 0.2 grams and 0.5 grams of rice husk charcoal adsorbent. This activity can be seen in Figure 4.

Figure 4. Student activities in experiment five.

In the final week, students performed complexometric titration to determine the calcium hardness of the adsorbed groundwater using 0.2 grams and 0.5 grams of rice husk charcoal adsorbent. This activity can be seen in Figure 5.

Figure 5. Student activities in experiment six.

The results of the worksheet assessment for the project implementation phase for each student can be seen in Table 8.

Table 8. Assessment results at the project implementation stage

Observed Aspects	Category	Number of Students	Score	Interpretation
Oservations Data	High	32		
	Medium	4	89.8	Very Good
	Low	0		
	Average		**89.8**	**Very Good**

Based on Table 8. The aspect of the observations data reached very good results with an average of 89.8. A total of 32 students were in the high category and 4 students in the medium category. Students in the high category showed the ability to collect structured data, observe important parameters in the adsorption process, and record titration results carefully. High performance demonstrated in observational data collection activities directly correlates with improved scientific performance, as structured laboratory experiences allow students to develop important scientific skills including hypothesis formulation, systematic evaluation of data, and construction of evidence-based conclusions, which are fundamental components of scientific literacy and academic achievement in chemistry education [21].

Students in the medium category had difficulties such as lack of accuracy in complexometric titration, lack of systematic observation of important parameters, difficulty analyzing data, and lack of accuracy in measuring adsorbent mass, water sample volume, and titrant volume.

Overall, the learning was successful in developing students' practical skills. However, it still needs improvement for students in the moderate category through intensive guidance, demonstration of laboratory techniques, and detailed use of formative assessment rubrics.

Develop draft/prototype product

The draft/prototype product stage involves literature review and product quality testing for interpretation of experimental results. In the literature review stage, students answered product evaluation questions using journals, books, and other sources as references. Data analysis and processing at the literature review stage is presented in Table 9.

TABLE 9. Assessment results at the draft/prototype product stage

Observed Aspects	Category	Number of Students	Score	Interpretation
Explaining complex compounds formed at the end of titration	High	31		
	Medium	5	95.4	Very Good
	Low	0		
Explaining the substances contained in adsorbents	High	24		
	Medium	6	83.3	Very Good
	Low	6		
	High	26		
Processing data from the experiment	Medium	7	78.7	Good
	Low	3		
Explaining the effect of adsorbent mass on reducing groundwater hardness	High	29		
	Medium	7	93.5	Very Good
	Low	0		
Comparing groundwater adsorption results with total hardness quality standards	High	33		
	Medium	3	97.2	Very Good
	Low	0		
Draw conclusions based on the problem formulation	High	26		
	Medium	10	90.7	Very Good
	Low	0		

Observed Aspects	Category	Number of Students	Score	Interpretation
Average			89.8	Very Good

Based on Table 9. The aspect of comparing groundwater adsorption results with total hardness quality standards is the aspect with the highest value, while the aspect of processing experimental data is the aspect with the lowest value, so at this stage the average value is 89.8 which is interpreted as very good.

The aspect of comparing groundwater adsorption results with total hardness quality standards is the aspect with the highest score of 97.2 which is interpreted as very good. There were 33 students in the high category and 3 students in the medium category. This achievement shows that almost all students are able to connect water quality standards based on Permenkes RI No. 32 of 2017 and analyze whether the results of reducing water hardness using rice husk charcoal adsorbent have fulfilled the specified safe or drinking water criteria.

The highest score in this aspect shows the success of learning in linking analytical chemistry concepts with everyday problems. Students not only understand the principles of complexometric titration and adsorption, but also able to analyze the data results with the improvement of water quality. The aspect of processing experimental data is the lowest score at this stage, although it is still classified as good with an average of 78.7. There were 26 students in the high category, 7 students in the medium category, and 3 students in the low category.

Data processing of experimental results is an important skill in scientific research, involving data analysis of EDTA titrant volume into Ca^{2+} and Mg^{2+} ion content, calculation of total hardness reduction, and analysis of adsorbent mass in contrast to adsorption efficiency. The relatively lower score in this aspect shows that data processing is an obstacle for students. This is due to the calculation of stoichiometry in complexometric titration.

The results of the overall assessment showed a very good achievement with an average of 89.8. This proves that project-based worksheets are effective in learning complexometric titration and its application to reduce water hardness using rice husk charcoal adsorbents. This study represents a significant advancement in chemistry education by pioneering the systematic integration of project-based worksheets with agricultural waste utilization for environmental remediation, creating a novel pedagogical framework that simultaneously addresses analytical chemistry competencies and sustainability challenges. Unlike traditional laboratory exercises that focus solely on technique mastery, this innovative approach transforms students into environmental problem-solvers by connecting theoretical knowledge of complexometric titration with practical applications of locally available rice husk charcoal as an eco-friendly adsorbent. According to [22] project-based worksheets provide a clear structure for students in collecting and analyzing data, thereby developing scientific performance skills.

From these results, it is necessary to strengthen data processing and emphasize learning that associates chemical concepts with daily problems to maintain learning motivation. It also equips students with the knowledge to participate in environmental conservation and sustainable technology development. This finding supports research highlighting the need for chemistry education to offer clear, actionable steps toward sustainability, linking environmental problem-solving with industrial understanding. Advances in green chemistry education show that integrating theory with practical applications enhances learning in both academic and industrial settings [23].

The draft/prototype stage involves product quality testing. Students assess the product using a checklist on a scale of 1-3. The assessment focuses on groundwater hardness after the adsorption process with rice husk charcoal adsorbent, as shown in Table 10.

Based on Table 10. The first to third aspects have the same final score of 100 while the fourth aspect, that is the adsorption process using 0.2 grams of rice husk charcoal adsorbent is more effective in reducing groundwater hardness than using 0.5 grams of rice husk charcoal adsorbent according to theory, is the lowest aspect at this stage.

The aspect of understanding the total water hardness value after adsorption showed that all students achieved perfect scores. The resulting product is below the quality standard of 500 mg/L according to Permenkes RI No. 32 of 2017. This achievement shows that students not only understand the complexometric titration procedure, its application in everyday life, but also the products produced by students from experiments meet the established clean or drinking water criteria.

TABLE 10. Assessment results at the stage of product assessment and improvement.

Observed Aspects	Category	Number of Students	Score	Interpretation
The total hardness value that has been adsorbed is below the quality standard, which is <500	High Medium Low	36 0 0	100	Very Good
Rice husk charcoal adsorbent can absorb Ca metal	High Medium Low	36 0 0	100	Very Good
Rice husk charcoal adsorbent can absorb Mg metal	High Medium Low	36 0 0	100	Very Good
The adsorption process using 0.2 grams of rice husk charcoal adsorbent is more effective in reducing groundwater hardness than using 0.5 grams of rice husk charcoal adsorbent according to theory.	High Medium Low	22 9 4	82.4	Very Good
Average			**95.6**	**Very Good**

In the aspect of understanding the ability of rice husk charcoal adsorbent to absorb calcium and magnesium metals, all students achieved perfect scores. Students understood that the absorption of Mg^{2+} and Ca^{2+} ions occurs due to the unbalanced attraction of particles on the surface of solid material [24] and understood the mechanism of adsorption through pore structure, functional groups, ion exchange, and the effect of ionic radius differences on selective adsorption.

The aspect of the effectiveness of adsorption based on adsorbent mass is the aspect with the lowest score of 82.4 which is interpreted as very good with 22 students in the high category, 9 in the medium category, and 4 in the low category. This aspect shows a diversity of understanding, especially in understanding why 0.5 grams of rice husk charcoal adsorbent is more effective in reducing water hardness than 0.2 grams and there are 4 students in the category of allowing constraints during the experiment to produce data that does not match the theory.

In theory, an increase in adsorbent mass should provide more active pores. However, several factors can cause the opposite phenomena, such as particle agglomeration that reduces the effective surface area and interparticle interactions that interfere with the adsorption process.

The assessment results overall showed a very good achievement with an average score of 95.6. This proves that the use of project-based worksheets effectively facilitates students' comprehension of complexometric titration and its application in reducing water hardness using rice husk charcoal adsorbent. In accordance with the research of [25] that the use of rice husk charcoal can be used as an adsorbent that absorbs metal ions and has a carbon content of 1.33% and a silica content of 16.98% so that it is easier to process and use as a natural adsorbent, especially in groundwater that experiences hardness.

Finalization and Publication

The final assignment in the practicum to reduce groundwater hardness by utilizing rice husk charcoal adsorbent, students are required to make a poster. This poster has a standard format that includes title, objectives, theoretical basis, results and discussion, conclusion, and bibliography. Based on the assessment, it can be seen in Table 11.

However, overall there were no student scores in the low category which can be seen in Table 12. Based on Tables 11 and 12, the objective aspect of the experiment has the highest score and the results and discussion aspect has the lowest score, so the average score at this stage is 86.7 which is interpreted as very good.

TABLE 11. Assessment results at the finalization and publication stage.

Observed Aspects	Category	Number of Students	Score	Interpretation
Title	High	33	97.2	Very Good
	Medium	3		
	Low	0		
Experiment Objective	High	36	100	Very Good
	Medium	0		
	Low	0		
Theoretical Basis	High	21	81.5	Very Good
	Medium	10		
	Low	5		
Results and Discussion	High	17	73.1	Baik
	Medium	9		
	Low	10		
Conclusion	High	23	83.3	Very Good
	Medium	8		
	Low	5		
Bibliography	High	23	85.2	Very Good
	Medium	10		
	Low	3		
	Average		**86.7**	**Very Good**

TABLE 12. Assessment results at the finalization and publication stage based on overall scores

Category	Number of Students	Average	Interpretation
High	30	86.7	Very Good
Medium	6		
Low	0		

The objective aspect of the experiment showed excellent results with all students scoring 100 with a very good interpretation. This achievement proves that students understand how to set research objectives that are clear, measurable, and relevant to the problem under study. The students successfully formulated objectives that included important parameters such as the principle of complexometric titration, adsorbent effectiveness, and the effect of rice husk charcoal adsorbent mass on reducing groundwater hardness.

The results and discussion aspect obtained the lowest score with an average of 73.1 which was interpreted as good. There were 17 students in the high category, 9 students in the medium category, and 10 students in the low category. This suboptimal ability shows that students experience problems in analyzing and comprehensively connecting experimental data. Students in the low category had difficulty processing quantitative data from complexometric titration, calculating hardness reduction, analyzing adsorbent effectiveness, explaining adsorption effectiveness based on adsorbent mass with theory, and explaining the relationship between research parameters and the results obtained. This was due to limited ability to connect theory with data, lack of statistical skills, and difficulty explaining research results in the context of broader scientific understanding.

The overall average poster score was 86.7, which is interpreted as very good. There were 30 students in the high category and 6 in the medium category. This shows a good understanding among students of the concept and application of complexometric titration and adsorption process in reducing groundwater hardness.

However, there were significant differences in students' abilities in various aspects with the results and discussion being the most complex aspects. This indicates the need for more emphasis on developing data analysis skills, including an in-depth understanding of the relationship between theoretical concepts and their application in the context of this experiment.

Based on each stage in the application of project-based worksheets in the utilization of rice husk charcoal adsorbents to reduce groundwater hardness, student involvement in project-based learning is very well implemented according to the graph in Figure 6.

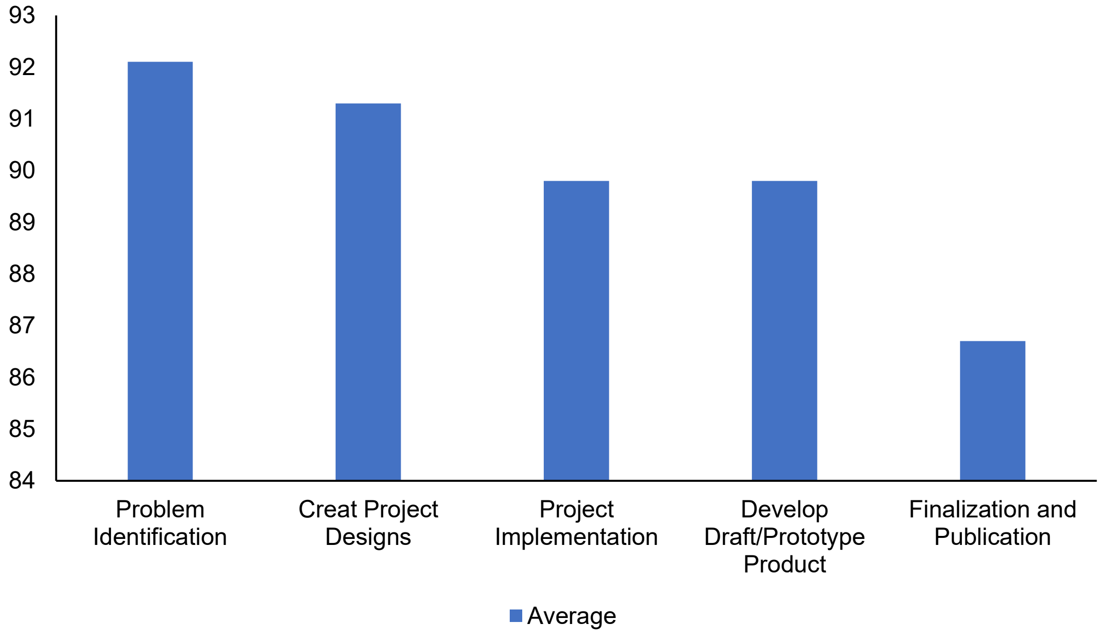

Figure 6. Average Value at the Project-based Worksheet Stage

Based on Figure 6. Each stage in the project-based worksheet work is at a very good interpretation. The problem identification stage and the project design stage show that students understand the problems and design solutions related to the use of rice husk charcoal adsorbent. The project implementation stage and the prototyping stage show the students' ability to apply theory to real practice well.

The finalization and publication stage achieved a score of 86.7 which remained in the excellent category, indicating that students were able to communicate the research results through posters effectively. Overall, all stages showed scores above 85, indicating that project-based learning on the use of rice husk charcoal adsorbent to reduce groundwater hardness is very effective in developing students' scientific performance.

The consistency of high scores in all stages indicates that this learning method successfully facilitates the development of students' scientific competence comprehensively, from problem identification ability to communication of research results. This is supported by the research of [26] who found that a project-based learning approach can develop students' scientific performance. This method encourages students to play an active role in planning projects and completing projects to achieve the set competency standards. The achievement of learning through project-based worksheets covers three domains, namely knowledge, attitudes, and skills. Through the project-based approach, students' abilities can be measured by conducting experiments, so as to develop students' scientific performance in carrying out experiments.

CONCLUSION

The application of project-based worksheets successfully developed students' scientific performance in utilizing rice husk charcoal as an adsorbent to reduce groundwater hardness, as evidenced by consistently high achievement scores across all learning stages: problem identification (92.1%), project design (91.3%), implementation (89.8%), prototype development (89.8%), product evaluation (95.6%), and finalization (86.7%). These quantitative results demonstrate that students effectively developed critical scientific competencies including hypothesis formulation, experimental design, data collection and analysis, and research communication. The integration of complexometric titration principles with sustainable agricultural waste utilization not only enhanced students' analytical chemistry understanding but also fostered environmental awareness and practical problem-solving skills. However, the study revealed specific areas requiring improvement, particularly in data processing and statistical analysis (78.7% average) and results discussion writing, indicating the need for enhanced support in quantitative reasoning and scientific communication skills. To address these deficiencies, future implementations should incorporate structured statistical analysis training sessions, provide standardized data processing templates, and implement peer review activities to strengthen students' scientific writing and analytical interpretation capabilities.

This research addresses a significant gap in chemistry education by pioneering the systematic integration of project-based learning with environmental remediation using locally available materials, contributing both pedagogical innovation and practical sustainability solutions. The findings demonstrate that authentic, hands-on learning experiences connecting theoretical knowledge with real-world applications can significantly enhance students' scientific literacy and critical thinking capabilities. Future research should investigate the long-term retention of these scientific competencies, explore adaptations for different educational contexts, and examine the scalability of this approach across various environmental chemistry topics to further strengthen evidence-based chemistry education practices.

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