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Application of Problem-Based Worksheets to Develop Higher Order Thinking Skills In The Utilization of Coconut Shells As Zn Metal Adsorbent In Laboratory Waste

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Abstract
This study aims to analyze scientific performance and analyze students' higher-order thinking skills after the application of problem-based LK to develop higher-order thinking skills in the use of coconut shell as an adsorbent for Zn metal in laboratory wastewater. The research method used is pre-experiment with one shot case study design. The subjects in this study were chemistry education students of UIN Sunan Gunung Djati Bandung who took separation chemistry courses. The instruments used are learning descriptions, LK, and higher order thinking skills questions. Students' higher-order thinking skills are measured through working on six HOTS questions based on the concept of Bloom's taxonomy level of thinking at cognitive levels C4 (analyze), C5 (Evaluate) and C6 (Create). The results showed that the average value of student performance in solving problem-based LK was 88.35 with a very good category. The highest average score achieved was at stage 2 organizing students with a score of 91.5 and a very good category. The lowest average value at stage 4 develops and presents results with a value of 86.25 and a very good category. The results of students' higher order thinking skills obtained an average score of 78 in the good category. Thus the application of problem-based LK on the utilization of coconut shell as a heavy metal adsorbent in laboratory wastewater can develop higher order thinking skills in students.

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INTRODUCTION

The 21st century is marked by the rapid development of technology and information, which demands Higher Order Thinking Skills (HOTS) (Almazroui, 2023; Chusni et al., 2020; Hulyadi et al., 2024). These skills include the ability to think critically, solve problems, make complex decisions, and innovate (Liline et al., 2024). In an educational context, the development of HOTS is very important because it helps students not only understand information in depth, but also apply it in complex real situations. HOTS encourages students to analyze, evaluate, and create new ideas, all of which are critical in facing global challenges in the 21st century (Loyens et al., 2023).

The ability to break information or concepts into smaller parts to understand their structure, identify patterns, and recognize relationships between elements (Kirman-Bilgin & Kala, 2022; Pennycook et al., 2012). Analysis is the foundation of HOTS (Liline et al., 2024). This ability allows students to not only receive information passively but also to understand and decipher that information (Miterianifa et al., 2021; Thorndahl & Stentoft, 2020). In the

context of global challenges of the 21st century, such as climate change, global economic dynamics, and environmental problems, analytical skills help individuals map problems, recognize causal factors, and identify opportunities and threats. The next component of high-level thinking is evaluation (Afdareza et al., 2020; Chusni et al., 2020; Dwyer et al., 2014; Hulyadi et al., 2024). Evaluation involves the ability to judge the value, validity, or effectiveness of an idea, argument, or solution based on certain criteria. Evaluation demands critical thinking skills which are at the core of HOTS. Students who are able to evaluate information can distinguish between facts and opinions, assess the credibility of sources, and make decisions based on evidence. In the 21st century, where information is abundant and often misleading, evaluation skills help students make informed and responsible decisions (Loyens et al., 2023; Shaw et al., 2020). HOTS involves the application of analytical and evaluative knowledge and skills to create something new. In facing 21st century challenges, such as the need for technological innovation or social solutions, creativity allows individuals to produce unprecedented approaches, which can pave the way for progress and more effective resolution of global problems (Higgins, 2014)

Raising environmental issues as the main focus in education is a very important fundamental step to take in an effort to form students' environmentally caring character. In the current era, environmental issues have become one of the main issues that not only impact ecological conditions but also affect social and economic aspects throughout the world. Climate change, pollution, deforestation, and depletion of natural resources are some examples of environmental problems that have broad implications for human life (Abbass et al., 2022). The impact of environmental degradation is not only limited to natural damage, but also disrupts social and economic stability. For example, the scarcity of natural resources such as water and fertile land can trigger conflict between communities and countries, while increasingly frequent natural disasters can cause large economic losses and exacerbate poverty in many regions (Carleton & Hsiang, 2016; Gasper et al., 2011).

Amin et al., 2020; Ashraf et al., (2018) stated that prioritizing the context of environmental issues is one of the strategies in cultivating environmental awareness and character in the younger generation. Education that emphasizes environmental issues can help students understand the complexity of these problems and motivate them to take environmentally responsible action. Thus, the integration of environmental issues in the educational curriculum not only functions as a transfer of knowledge, but also as a means of character formation (Amin et al., 2020). Environmentally based education can also provide students with real experience in importance of protecting the environment through practical activities, such as recycling, greening or waste management projects at school. This kind of activity not only increases students' understanding of the importance of the environment, but also instills values such as care, responsibility, and social awareness (Birgili, 2015).

Environmental education is an education designed for students to have knowledge, attitudes, and behaviors that are rational and responsible for the use and processing of natural resources (Maryuningsih, 2012). Environmental education aims to increase knowledge and awareness of environmental values. The importance of environmental education for students has been applied since high school to college level, one of which is in the separation chemistry course (Mulyono et al., 2012: 21). Separation chemistry courses not only teach theory but also emphasize practicum activities so that it is expected to develop students' scientific performance. The process of developing scientific performance requires teaching materials that can support in knowing students' scientific performance abilities. One type of teaching material that is appropriate to develop is worksheets (LK). The worksheet contains a set of basic activities that must be carried out by students to maximize understanding in an effort to form basic abilities in accordance with the achievement indicators taken. The use of LK can

help students identify, apply, and combine various concepts that have been learned. LK serves as a guide in learning and carrying out practicum (Lase et al., 2022).

In learning activities, in addition to using LK as a learning medium, a learning model is also needed that can encourage students to become more actively involved in learning activities. One alternative learning model that can be used to develop students' higher order thinking skills in solving problems is Problem Based Learning (PBL) (Khairunisa et al., 2020).

The stages of problem-based LK consist of five stages, including 1) orienting students to the problem, 2) organizing students to learn, 3) guiding individual and group investigations to get the right information, 4) developing and presenting results, 5) analyzing and evaluating the problem solving process (Mahardika et al., 2022). The use of problem-based LK makes students become more actively involved in understanding the concepts and principles of a material so that it will affect students' higher-level thinking skills (Paat et al., 2021). This is supported by research (Susilawati et al., 2017) which indicates that the application of the PBL model encourages the active involvement of students in solving problems, thus having an impact on improving students' higher-order thinking skills. High-level thinking skills include the cognitive domains of analyzing (C4), evaluating (C5) and creating (C6) (Prasetyani et al., 2016). Bloom's cognitive domain in higher-order thinking skills is expected to guide students in solving environmental problems that occur in everyday life, for example related to the issue of laboratory wastewater pollution.

Laboratory liquid waste is included in the B3 waste group which comes from expired raw materials, consumables, products of laboratory activities, products of waste handling efforts, residual chemicals that have been used, used water from washing equipment and samples left over from trials (Nurhayati et al., 2018). Laboratory wastewater contains hazardous chemical compounds, including heavy metals such as zinc (Zn). Heavy metals can cause poisoning in living cells such as plants, animals and humans if not managed properly. Therefore, an appropriate laboratory liquid waste treatment method is needed to reduce the concentration of heavy metal hazardous substances contained in the liquid waste, so that it reaches the allowed quality standards before the waste enters the community environment (Marisa & Rahayu, 2016). Reducing the concentration of heavy metals in laboratory wastewater can be done by adsorption method. Adsorption is a process of absorption by certain solids of certain substances that occur on the surface of the solid, this is influenced by the attractive force between atoms or molecules on the surface of the solid without seeping in. The substance that undergoes the adsorption process is called the adsorbate and the substance that performs the absorption is called the adsorbent (Midwar et al., 2018).

The adsorption process can be carried out using natural adsorbents by utilizing organic materials. The advantage of utilizing natural adsorbents in reducing hazardous and toxic metal levels in the environment is that the materials are easily obtained and are environmentally friendly. This adsorption process uses organic material in the form of oil palm by utilizing the shell. Coconut shell can be utilized as a natural adsorbent in adsorbing heavy metals because it contains lignin, cellulose, and hemicellulose as metal ion absorbers (Mandasari & Purnomo, 2016). This refers to the research of Ulva A'yunina et al. (2022) which shows that the utilization of coconut shell adsorbents has several advantages, namely a larger absorption surface area (500 m2/g). In a combination of complex physical and chemical reactions, coconut shell adsorbent is indicated to bind metal ions on its surface.

In connection with the research described above, there has been no research on the utilization of coconut shell as an adsorbent for Zn metal in laboratory liquid waste with the help of problem-based worksheets. Referring to this, the researcher is interested in making a study on "Application of Problem-Based Worksheets to Develop Higher Level Thinking Skills on the Utilization of Coconut Shell as a Zn Metal Adsorbent in Laboratory Liquid Waste".

METHOD

The research procedure can be seen in Figure 1.

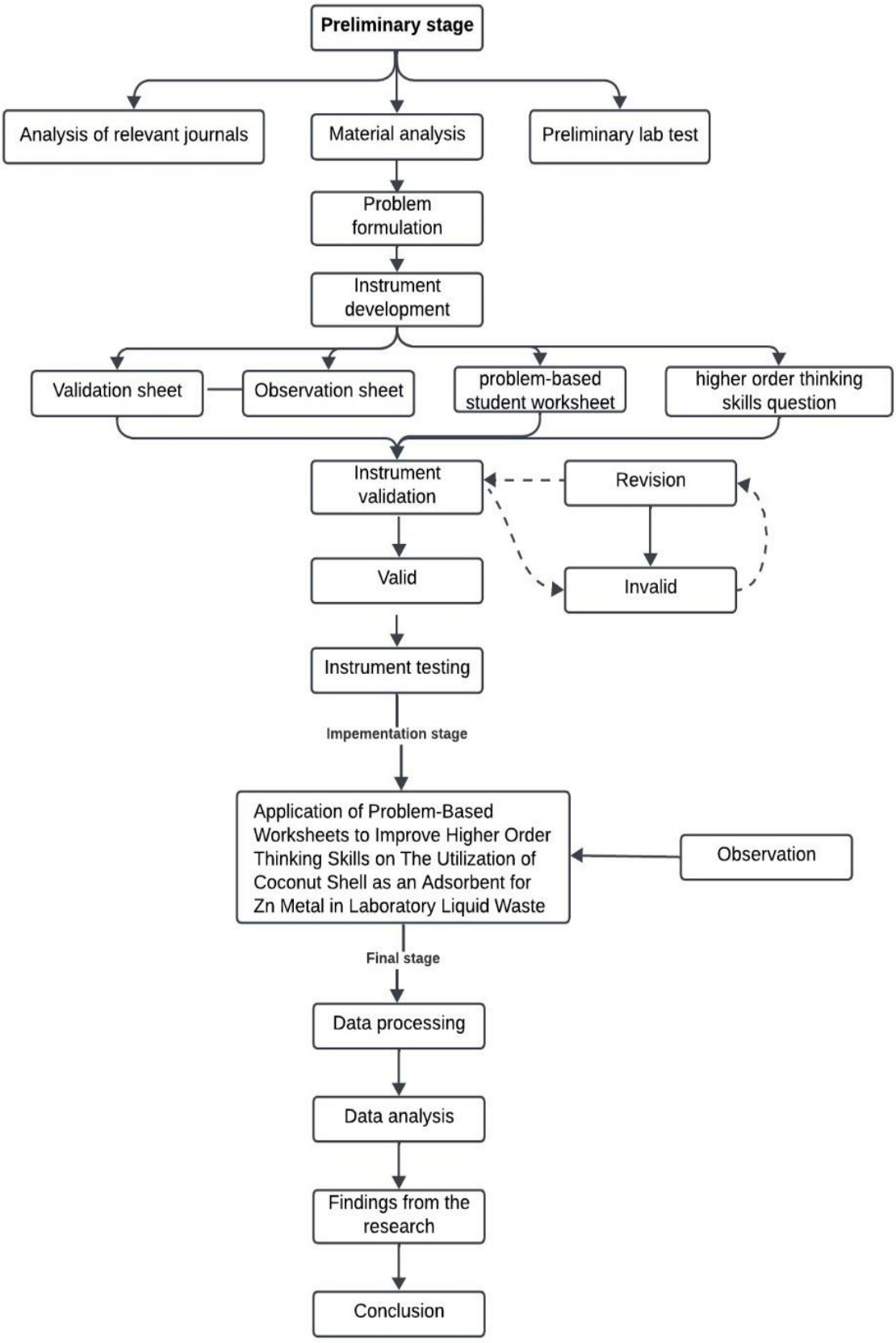

Figure 1. Research Procedures

This study uses a pre-experiment method with the type of research design, namely one shot case study (class research), this approach refers to the research method book by (Sugiyono, 2017). The one-shot case study design according to (Arikunto, 2013) is carried out only by conducting one treatment which is thought to have had an effect, then a post-test is held. This provides convenience for researchers who have limited time, resources, or access to the population or sample. The treatment given in this study is the application of problem-based LK in the utilization of coconut shell as an adsorbent for Zn metal in laboratory liquid waste and working on six evaluation questions developed with a cognitive level of higher order thinking skills consisting of C4 (analyze), C5 (evaluate) and C6 (create). There are three procedures in the research, which include the preparation, implementation, and final stages.

In the preparation stage, an analysis of environmental problems, problem-based LK analysis and material analysis regarding separation chemistry practicum focusing on complexometric titration, conducting preliminary tests, compiling instruments and conducting instrument validation tests. In the next stage, the implementation stage begins with carrying out the practicum on the utilization of coconut shell as an adsorbent for Zn metal in laboratory liquid waste by working on LKs that follow the stages of problem-based learning and working on six questions on higher order thinking skills. In the final stage, test the results of the application of LK to students, analyze and process data and compile a research report.

RESULTS AND DISCUSSION

Based on the research conducted, the following results were obtained:

Description of Student Scientific Performance on the application of Problem-based Worksheets In The Utilization Of Coconut Shells As Zn Metal Adsorbent In Laboratory Waste

Research on the application of problem-based LK in the utilization of coconut shells as Zn metal adsorbent in laboratory waste was carried out in one meeting at the Integrated Laboratory of Chemical Education. The implementation was carried out on May 23, 2023. The activities can be seen in Figure 2 below.

Figure. 2 Application of Problem-based LK

The application of this LK begins with introductory activities to provide apperception and motivate students before starting learning. After that, followed by core activities, students do

complexometric titration practicum and work on LK that has been equipped with PBL stages. Overall, the core activities went quite well. This is evidenced by the scientific performance of students at each stage of the LK in accordance with the predetermined time. Students also look so active discussing with their group mates and practicum activities run well and orderly. The detailed explanation of each stage of the problem-based LK is:

Student Orientation Stage

The first stage in problem-based LK is orienting students to the problem. At this stage, students conduct discussions to identify the main idea of the paragraph, formulate problems and make hypotheses. Students' scientific performance at stage 1, namely the stage of orienting students to the problem, is good. The average value of students' ability to identify main ideas, formulate problems and make hypotheses received a score of 85.75 in the very good category. The results of student assessment on problem-based LK at stage 1 of orienting students to the problem can be seen in Table.1 below.

Table 1. The Value of Each Group's Ability to Complete LK at Stage 1 Orienting Students to the Problem

No	Group	Questions (Score max)			Total Score (11)	Score	Interpretation
		1 (5)	2 (3)	3 (3)			
1	5B	3	2	2	7	63	Enough
2	6B	4	3	3	10	90	Very Good
3	7B	4	3	3	10	90	Very Good
4	8B	5	3	3	11	100	Very Good
Mean		4	2,75	2,75	9,5	85,75	Very Good

The problem-orienting stage carried out at the beginning of problem-based LK learning aims to help students develop creativity in solving a problem so that students can understand and master the concepts in the material being studied (Widdy Sukma Nugraha, 2018).

Organizing Students Stage

The second stage in problem-based LK is the stage of organizing students. At this stage, each group conducted a discussion on the material of utilizing coconut shell as an adsorbent for Zn metal in laboratory wastewater using complexometric titration. Discussion to determine the principle of complexometric titration experiment. In the stage of organizing students, the discussion activities carried out have the aim of training students to respect each other's opinions. Through this activity, learners are invited to accept various answers with good understanding, without any difference in understanding between group members. In addition, discussion activities also play a role in training students' emotional intelligence skills (Aspridanel et al., 2019).

Based on the researcher's observation, the answers of some groups were correct, students could explain well about the principle of complexometric titration in the utilization of coconut shell as an adsorbent for Zn metal in laboratory wastewater. However, there are still answers that are less relevant due to group discussions conducted by students that are still not optimal. Students still do not understand well how the principle of the experiment in the discourse and modules available. Students' scientific performance at stage 2, namely the stage of organizing students on the problem in conducting discussions and determining the principles of practicum, is good. The average score of students' abilities at stage 2 received a score of 91.5 with a very good category. The results of student assessment on problem-based LK at stage 2 organizing students can be seen in Table 2.

Table 2. Ability Score of Each Group in Completing LK at Stage 2 Organizing Students

No	Group	Score	Total Score	Score	Interpretation
1	5B	2	3	66	Good
2	6B	3	3	100	Very Good
3	7B	3	3	100	Very Good
4	8B	3	3	100	Very Good
Mean		2,75	3	91,5	Very Good

Guiding Inquiry Stage

The third stage in this problem-based LK is guiding the investigation. At this stage, students determine the tools and materials used in practicum activities and design the design of the complexometric titration experiment. Based on the results of observations, the flow chart made by students is correct and complete, each procedure is also equipped with hypotheses including physical and chemical properties to make it easier for them to observe the results of the experiment. The activity of designing an experimental design is included in the highest level in the cognitive level with the characteristics of questions that produce a work or idea (Anderson & Krathwohl, 2017) so that in this case the application of problem-based LK is effective in developing higher-level thinking skills in students.

Overall, students' scientific performance at stage 3, namely the stage of guiding investigations in determining material tools and designing experimental procedures, was good. The average score of each group's ability at this stage is 88.25 with a very good category. The results of student assessment of problem-based LK at stage 3 guiding the investigation are shown in Table 3. below.

Table 3. The Value of Each Group's Ability to Complete Problem-Based LK at Stage 3 Guiding Investigation

No.	Group	Questions (Score max)		Total Score (9)	Score	Interpretation
		5 (4)	6 (5)			
1	5B	3	5	8	88	Very Good
2	6B	4	4	8	88	Very Good
3	7B	3	4	7	77	Good
4	8B	4	5	9	100	Very Good
Mean		3,5	4,5	8	88,25	Very Good

Developing and Presenting Results

The fourth stage in problem-based LK is the stage of developing and presenting results. At this stage, students together with their group friends fill in and complete the observation data containing treatments and observations and solve problems related to the experimental data. The topics of the questions discussed include questions about determining the level of Zn metal, determining the sample that has the best adsorption absorption and making conclusions based on the results of the experiment.

Students' scientific performance at stage 4, namely the stage of developing and presenting results in completing observation data, determining Zn levels and determining which samples have the best adsorption power and in making conclusions is good. The average score of each group's ability at this stage is 86.25 with a very good category. The results of student assessment of problem-based LK at stage 4 developing and presenting results are shown in Table.4 below.

Table 4. The Value of Each Group's Ability to Complete Problem-Based LK at Stage 4 Developing and Presenting Results

No.	Group	Questions (Score max)				Total Score (15)	Score	Interpretation
		7 (5)	8 (3)	9 (3)	10 (4)			
1	5B	4	3	3	4	14	93	Very Good
2	6B	3	3	3	4	13	86	Very Good
3	7B	5	3	2	3	13	86	Very Good
4	8B	4	2	3	3	12	80	Very Good
Mean		4	2,75	2,75	3,5	13	86,25	Very Good

Analyzing and Evaluating Stage

The fifth or final stage of problem-based LK is the analyzing and evaluating stage. At this stage, students present the results of the experiment in front of other groups. Based on the results of the researcher's observations, each group representative has presented the results of the experiment well. They conveyed the procedures and results of the experiments that had been carried out clearly and straightforwardly. The results of student assessment of problem-based LK at stage 5 analyzing and evaluating are shown in Table 5.

Table 5. Value of Each Group's Ability to Complete Problem-Based LK at Stage 5 Analyzing and Evaluating

No	Group	Score	Total Score	Score	Interpretation
1	5B	4	5	80	Very Good
2	6B	4	5	80	Very Good
3	7B	5	5	100	Very Good
4	8B	5	5	100	Very Good
Mean		4,5	5	90	Very Good

Overall, the implementation of problem-based LK in the utilization of coconut shell as an adsorbent for Zn metal in laboratory liquid waste went very well. The average value of the overall problem-based LK work is 88.35 with a very good category. This means that problem-based LK can develop students' scientific performance in carrying out practicum, especially in separation chemistry practicum on complexometric titration material. Scientific performance is an activity to get answers to problems or questions that use a process skills approach such as skills to observe, question, interpret, classify, draw conclusions and communicate (Trihastuti et al., 2019). According to Yuliana et al. (2016) scientific performance is an intellectual skill possessed and used by scientists in researching natural phenomena. Indicators of scientific performance measured in this study are the ability of students to solve problems, use tools and materials, collect data, analyze data, conclude and communicate practicum results. Students who have scientific performance tend to have an independent attitude in the learning process (Martuti & Muharjito, 2013).

The overall data regarding the application of problem-based LK can be seen in Table 6.

Table 6. Recapitulation of the Value of Each Group in Solving Problem-Based LKS

No.	Group	Stages of Problem Based Learning					Mean	Interpretation
		1	2	3	4	5		
1	5B	63	66	88	93	80	78	Good
2	6B	90	100	88	86	80	88,8	Very Good
3	7B	90	100	77	86	100	90,6	Very Good
4	8B	100	100	100	80	100	96	Very Good
Mean		85,75	91,5	88,25	86,25	90	88,35	Very Good

After completing the practicum and working on the LK, the closing activity was continued. In this activity, reflection activities and material reinforcement are carried out to strengthen students' understanding of the material that has been learned so that misconceptions do not occur.

Analysis of Students' Higher Level Thinking Ability After the Application of Problem-Based Worksheets In The Utilization Of Coconut Shells As Zn Metal Adsorbent In Laboratory Waste

After completing the practicum and working on the LK, students were given several questions. This question is a question of higher order thinking skills that was done by 16 students who had previously participated in the practicum. The questions given were in the form of material regarding theory and practicum results and other insights into the utilization of coconut shell as an adsorbent for Zn metal in laboratory wastewater. This question aims to develop students' higher order thinking skills through the cognitive levels of C4, C5 and C6 and to measure the extent to which students have higher order thinking skills after the application of problem-based LK. The results of students' scores in working on higher order thinking skills are presented in Table 7.

Table 7. Recapitulation of the Value of Higher Order Thinking Ability Questions at Each Cognitive Level

Cognitive level	No. Question	Score	Mean	Interpretation
C4 : Analyze	1	75	78	Good
	2	81		
C5 : Evaluate	3	83	80	Very Good
	4	77		
C6 : Create	5	71	77	Good
	6	83		

Based on the recapitulation table of high level thinking ability question scores above, several factors cause the average student score to still not be optimal, namely due to lack of student concentration in working on problems, students have not been trained or accustomed to analyzing a problem in the problem, and students still have difficulty initiating new ideas in solving problems. The more detailed explanation for each question and cognitive level is as follows.

In question No. 1 and No. 3 covers the C4 cognitive level, namely analyzing. Students analyze how pH affects the adsorption process in absorbing harmful particulates in waste and analyze the purity of adsorbents that are well used to treat laboratory wastewater. The level of cognitive domain C4 (analyzing) is enough to hone the ability to think at a high level, because students are trained to break down and identify information in the problem into an organized structure (Saraswati & Agustika, 2020).

The average value of students' higher-level thinking skills in question No. 1 is 75 with a good category and in question No.3 is 81 with a very good category. While the recapitulation of the value of higher order thinking skills at the C4 cognitive level is 78 with a good category. Based on the results of observations of researchers, there are still some students who have not maximized in working on questions with this C4 cognitive level. Some factors that influence this such as lack of student concentration in working on problems or students have not been trained in analyzing a problem in the problem.

In question No. 2 and No. 5 includes cognitive level C5 which is evaluating. Students compared which adsorbent mass variable had the best absorption capacity in reducing heavy metal levels and correlated the effect of mass variables on the adsorption process. In addition, students also check the concentration of calcium contained in blood samples as a form of application of complexometric titration in the medical field. Both questions were answered well by the students. The average value of students' higher order thinking skills in question No. 2 is 83 with a very good category and in question No.5 is 77 with a good category. While the recapitulation of the value of higher order thinking skills at the C5 cognitive level is 80 with a good category. Based on the results of observations of researchers, the highest value of students in solving this high-level thinking ability problem is at the C5 cognitive level. This is evidenced by research conducted by (Kusuma et al., 2017) that the C5 cognitive level questions with the question model comparing, correcting, concluding and interpreting are categorized as very good in developing higher order thinking skills.

In question No. 4 and No. 6 includes cognitive level C6 which is creating. Students design an experiment to determine the level of Zn metal in drugs using the complexometric titration method and collect and detail information about the appropriate metal indicators used in complexometric titration. In the part of the question of designing experimental designs, there are still some students who write their answers inaccurately and incompletely. This can be caused because at this cognitive level it is quite difficult for students to initiate new ideas in solving problems. The C6 cognitive domain (creating) is effective in developing higher order thinking skills because it trains students' complex thinking to create new ways of thinking that have never been done before (Fajrilia et al., 2019). Meanwhile, in the part of the question about collecting and detailing information, the answers written by students are good. The average value of students' higher-level thinking skills in question No. 4 is 71 with a good category and in question No.6 is 83 with a very good category. While the recapitulation of the value of higher order thinking skills at the C6 cognitive level is 77 with a good category.

Each LK stage and cognitive ability on the level thinking ability question gets a range of scores between 70.64 to 81.28 which is categorized as high. In line with research conducted by Fajrilia et al., (2019) which states that problem-based LK, learning focuses on students and is contextual in nature. So that students become more actively involved directly in finding solutions to solving a problem which can develop their high-level thinking skills.

CONCLUSION

Based on the results of research that has been conducted on VI semester students of the Chemistry Education study program, Faculty of Tarbiyah and Keguruan UIN Sunan Gunung Djati Bandung in the 2023 academic year, the application of problem-based LK in the utilization of coconut shell as an adsorbent for Zn metal in laboratory wastewater can be concluded that students' scientific performance during the application of LK obtained an average score of 88.35 with a very good category. This shows that students can fill in or work on problem-based LK in the utilization of coconut shells as an adsorbent for Zn metal in laboratory wastewater very well. Students' higher order thinking skills after the application of problem-based LK in the utilization of coconut shells as an adsorbent for Zn metal in laboratory wastewater get good results with an average score at each cognitive level of 78. At the cognitive level of analyzing (C4) the average score is 78 with a good category, at the cognitive level of analyzing (C5) the average score is 80 with a very good category and at the cognitive level of creating (C6) the average score is 77 with a good category. With results like this indicate that problem-based LK is able to develop higher order thinking in students.

RECOMMENDATIONS

The suggestion describes the things to be done related to the next idea of the study. Obstacles or problems that can affect the results of the study are also presented in this section.

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