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Enhancing Critical Thinking Skills through Project-Based Chemistry Practicum Using Seaweed Hydrogel Design

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Abstract: This study explores the effectiveness of a project-based chemistry practicum in enhancing critical thinking and conceptual understanding among chemistry teacher candidates. Using a seaweed-based hydrogel as a medium for adsorbing metal ions, the practicum incorporates contextual learning processes, including problem investigation, collaborative engagement, and technology design. Conducted with 36 students at Pattimura University, the study applied a mixed-methods approach, combining qualitative observations and quantitative data analysis. Results indicate significant improvements in students' critical thinking, as evidenced by an N-Gain of 0.72, enhanced worksheet scores, and better practicum outcomes. The findings underscore the importance of integrating environmental resources and technological tools in practicum activities to foster creativity and innovation. However, the study highlights the need for adequate laboratory resources, extended practicum time, and advanced rubrics to assess complex learning outcomes effectively. These insights contribute to the development of advanced chemistry practicum models that align with 21st-century learning skills.

INTRODUCTION

Chemistry learning in the 21st century is faced with low motivation and active student involvement, including chemistry practicum activities (Sabila & Gunawan, 2019; Saimon et al., 2023; Wissinger et al., 2021). Chemistry is a basic science that helps us understand nature and the surrounding environment. Through chemistry learning, students can understand the properties and structure of matter, chemical reactions in nature, and how substances interact. In addition to impacting various fields, including health and the environment, chemistry learning is essential for developing critical thinking skills and analytical abilities for problem-solving in learning and professional careers (Nold, 2017; Saputra et al., 2023; Young et al., 2023).

Chemistry learning in practicum activities provides broad opportunities for students to apply theoretical concepts. Chemistry practicum should be designed and trained to develop students' critical thinking skills, thus allowing them to explore, generate, and practice concepts (Boz et al., 2019; Kristianto et al., 2023; Nurrahman et al., 2020; Pamenang et al., 2020; Sajidan et al., 2022).

Conventional practicum is considered ineffective in developing thinking skills that have an impact on student learning outcomes (Figueiredo et al., 2016). This practicum is more instructional without the active involvement of students in problem-solving; activities in each group are also only dominated by certain students, so there is less collaboration between students. Practicum by asking problems in the form of critical questions, designing, analyzing data, and making conclusions through group collaboration contributes positively and effectively to increasing student motivation and engagement (Bretz, 2019; Seery, 2020). This practicum activity requires collaboration, planning, and critical thinking of students (Genc, 2015; Pan et al., 2021).

Critical thinking skills are one of the thinking skills that contribute to problem-solving encountered in practicum and decision-making to produce original and innovative products (Bellaera et al., 2021; Goyal et al., 2022; Lithoxoidou & Georgiadou, 2023; Young et al., 2023). This thinking skill is the cognitive ability to analyze and identify complex information, interpret data and its solutions, and make conclusions (Helaluddin et al., 2023; Liyanage et al., 2021; Rohm et al., 2021; Sinaga et al., 2022; Brederode et al., 2020; Young et al., 2023). According to Janse van Rensburg & Rauscher (2022) dan Quinn et al (2020), critical thinking skills are the ability to assess an argument rationally, understand the relationship of each problem, and identify biases in decision-making so that students can solve problems appropriately and effectively.

The development and implementation of a project-based chemistry practicum focused on problem-solving is carried out to improve students' critical thinking skills and conceptual understanding. This method is able to motivate students to analyze the information obtained, synthesize new ideas that support the results of the analysis, and actively participate in group discussions. Students with the ability to analyze, solve problems, formulate conclusions, and make the right decisions usually have good critical thinking skills (Sabila & Gunawan, 2019; Sanchez, 2021; Brederode et al., 2020; Zhang & Chen, 2021). According to Zemel et al (2021) dan Almulla (2020), critical thinking skills in project-based practicum play a significant role in learning innovation. Students will be actively involved in analyzing problems and making hypotheses for critical problem-solving (Chen et al., 2022; Gomez-del Rio & Rodriguez, 2022; Ngereja et al., 2020; Saimon et al., 2023; Sumarni & Kadarwati, 2020).

The use of natural materials found around the student environment as materials in contextual-based practicum projects has proven to be effective in improving learning outcomes (Amizera et al., 2023; Sari et al., 2020; Ulvik et al., 2023). Project-based chemistry practicum, which involves designing seaweed materials into hydrogels to adsorb metal ions, has been carried out collaboratively by students using diverse and innovative strategies for problem-solving. The application of this seaweed project-based practicum method is considered appropriate and effective for improving critical thinking skills and mastery of chemical concepts.

METHOD

The research was conducted in a chemistry laboratory using mixed methods of exploratory design, which involves the development and implementation of quantitative instruments based on qualitative findings (Creswell & Plano Clark, 2010). The research sample is 36 prospective chemistry teacher students at educational institutions at Pattimura University for the 2023/2024 academic year. The project-based practicum was adopted from Pan et al. (2021), with the following stages: investigating questions, exploring questions, engaging collaboratively to get solutions, and designing technology and outputs. Critical thinking skills use indicators, according to Ennis.

Quantitative data analysis from the test results was in the form of a score improvement test using the N-Gain test, a normality test using the Kolmogorov-Smirnov Test, a non-parametric test using the Wilcoxon test, an effect size test using the Effect Size Calculator (Cohen's D), and a Pearson correlation test. Qualitative data analysis was obtained from the results of answering questions in worksheets, developing critical thinking skills in practicum activities, and implementing practicum.

The practicum begins with students studying chemical materials and seaweed hydrogels; then, project assignments are carried out based on the instructions on the worksheet. During the practicum, students design project assignments according to the topic and objectives of the practicum, conduct tests and collect data, create reports, and present them. The flow of student activities in the project-based chemistry practicum can be seen in Figure 1.

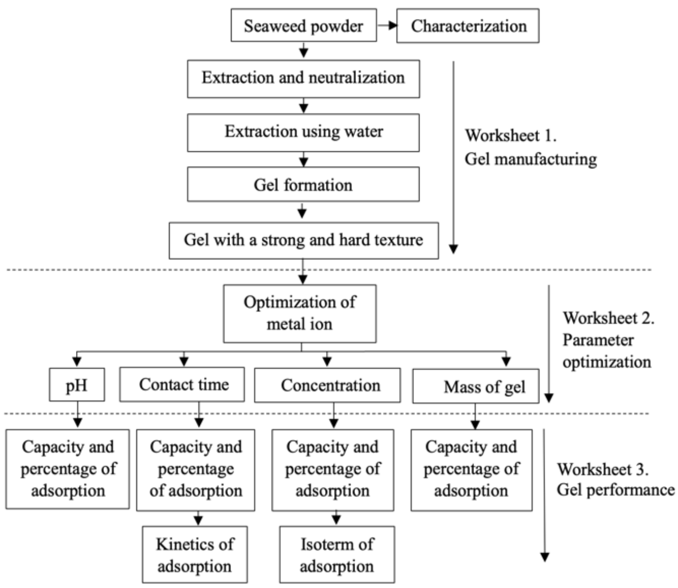

Figure 1. Project-Based Practicum Flow.

RESULT AND DISCUSSION

Practicum becomes unsuccessful due to students' low critical thinking skills and understanding of theoretical concepts, which is overcome through the use of active learning and the integration of theoretical concepts into practicum. Another problem is that the practicum has not connected the theoretical concepts practiced with contextual aspects. Project-based chemistry practicum through the manufacture of seaweed hydrogel to adsorb metal ions needs to be done by students to overcome it; this activity not only improves the understanding of concepts but also significantly improves students' critical thinking skills. The results of the analysis of the increase in students' critical thinking skills test scores are seen in Table 1.

Table 1. Critical Thinking Skills Test Results.

Aspects	Average Grade		N-Gain
	Pretest	Posttest	
Elementary clarification	19	76	**0.72 (High)**
Basic suport	39	92	
Inference	18	84	
Advance clarification	31	96	
Strategy and tactics	14	64	

The test results showed improvements in every aspect of critical thinking skills. This is supported by research conducted by Aranzabal et al. (2022) regarding higher test scores in students who have active and effective performance in completing project-based practicum assignments. According to Sari et al. (2020), the improvement of critical thinking skills and chemistry learning outcomes is also due to the use of materials from the environment around students in project-based practicums. The increase in test scores was also evidenced by the results of the normality test ($p<0.05$), the Wilcoxon test ($0.000<0.05$), and the effect size test ($d>2.0$), which showed a difference in test results where practicum had a strong influence on students' critical thinking skills. The results of the Pearson correlation test ($0.000<0.05$) also showed a perfect correlation between critical thinking skills and concept mastery.

Activities in project-based practicum also contribute to students' cognitive skills, where practicum activities that bring up aspects of critical thinking skills can have a significant impact on students' high thinking skills in analyzing problems and making conclusions for problem-solving. This research successfully developed a practicum worksheet based on a grass project through the stages of making seaweed gel, optimizing measurement parameters, and testing the performance of seaweed gel against metal ions. The results were obtained to improve students' critical thinking skills in chemistry. Research by Brederode et al. (2020) found that practicum worksheets containing questions to measure critical thinking skills were considered to be able to improve student's critical thinking skills. The results of the analysis of the answers to the questions on the student worksheet are shown in Figure 2.

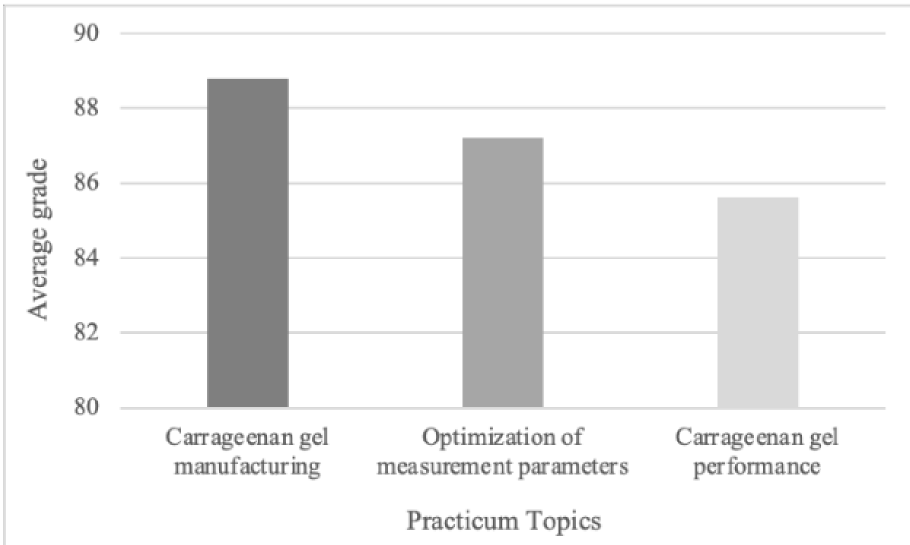

Figure 2. Results of Analysis of Question Answers on Student Worksheets.

These results show that students have critical thinking skills and excellent cognitive abilities in each practicum topic. This is in line with the results of Pamenang et al. (2020) research that the development of chemistry practicum modules has been proven to motivate students to design experiments, analyze practicum needs carefully, and reflect on their learning experiences. The results of the analysis of critical thinking skills in practicum activities are seen in Figure 3.

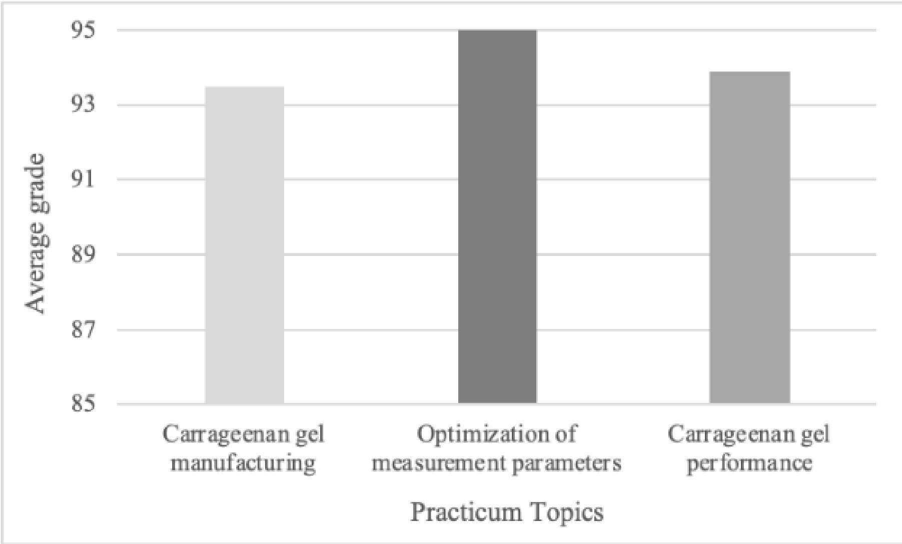

Figure 3. Results of Critical Thinking Skills Analysis in Practicum Activities.

The results indicate that critical thinking skills significantly contribute to the success of practicum activities, enabling students to effectively conduct practicum sessions in accordance with the stages of a project-based practicum. This finding aligns with the study by Araújo et al. (2022), which demonstrated a 77.8% average improvement in students' conceptual understanding and critical thinking skills during a project-based chemistry practicum. Furthermore, the outcomes reveal that the practicum was implemented optimally, resulting in the development of innovative products. The analysis of the practicum implementation is illustrated in Figure 4.

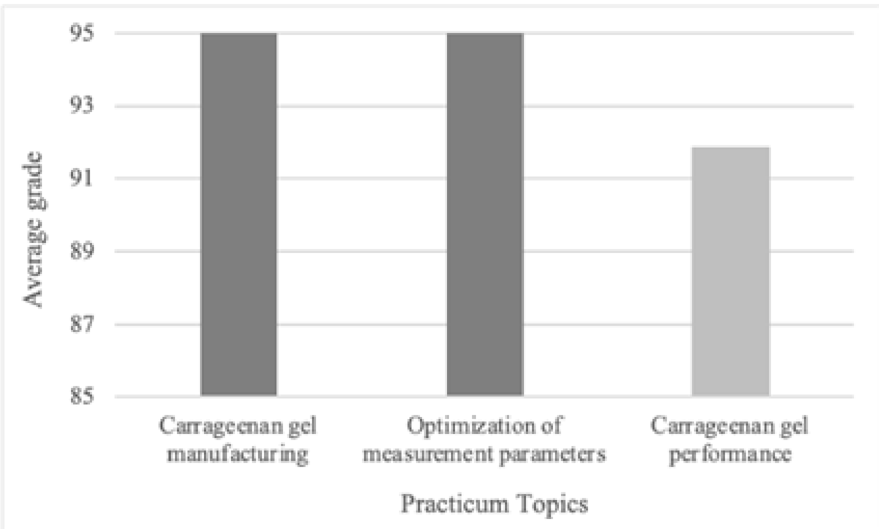

Figure 4. Results of Observation Analysis of Practicum Implementation.

The project-based practicum begins with picking seaweed in the waters, then students wash and dry the grass. The dried seaweed is then pureed. This process aims to obtain a powder that is clean and does not contain contaminants. Through the information and instructions on the worksheet, students then design the manufacture of seaweed-based hydrogels, optimize them, and test their performance against metal ions. The results of the practicum are seen in Figure 5.

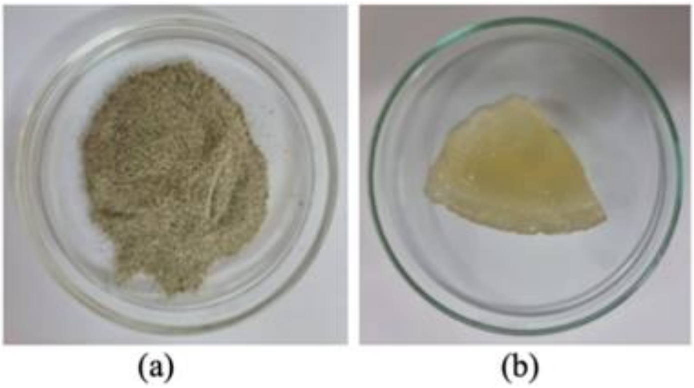

Figure 5. Seaweed (a) Powder, (b) Hydrogel

These results show that project-based practicum is able to improve students' critical thinking skills and understanding of concepts. At this stage, students design seaweed hydrogels according to the instructions on the worksheet. The biosorbent resulting from this design has proven to be effective in absorbing metal ions in the water. This is in line with the research of Li et al. (2020), which found that project-based practicum is able to improve students' design skills, presentation skills, and conceptual understanding. The design and assessment of project-based practicum was also carried out by Gomez-del Rio & Rodriguez (2022), where 85% of students were able to design and measure a 3D model on the topic of elasticity and strength of materials. The development and implementation of contextual-based practicum is able to significantly improve critical thinking skills and understanding of chemical concepts. These results are inseparable from student collaboration in groups and the design of worksheets designed to improve students' critical thinking skills.

CONCLUSION

A project-based practicum is able to improve critical thinking skills and understanding of concepts. Students' critical thinking skills based on the answers to questions on the worksheet, practicum activities, and practicum implementation with a score of >85.0 and a test score with N-Gain of 0.72 prove that project-based chemistry practicum through seaweed design to adsorb metal ions precisely and effectively improves students' critical thinking skills. Improving students' critical thinking skills and understanding of concepts to the maximum can be done through contextual scenarios that are applicable using potential materials and technology around life to encourage student creativity. This practicum still requires a more complex assessment rubric to assess learning outcomes.

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