JPPIPA 10(4) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Project-Based Learning in Teaching Adsorption Isotherm: The Implementation and Students' Opinion

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Received: October 02, 2023
Revised: January 19, 2024
Accepted: April 25, 2024
Published: April 30, 2024

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DOI: 10.29303/jppipa.v10i4.5543

Abstract: Project Based Learning is one of the learning models that can be chosen by lecturers in learning activities. This learning model is applied in surface chemistry learning, especially on the topic of the adsorption isotherm models. This research aims to find out more about implementation and students' opinions in project-based learning models. This study employs a mixed-method research approach, utilizing both questionnaires and documentation as data collection methods. The questionnaire instrument consisted of an open and closed questionnaire for the respondents. An open and closed questionnaire was used to collect respondents' descriptive data on the perception of the model. The project-based learning model received a positive response from students. This positive feedback encompasses interactions with the lecturer, motivation to learn, comprehension of the material, and the execution of project-based learning. This model recognized for its capacity to foster profound comprehension of subject matter, cultivate advanced cognitive skills, and stimulate learners' intrinsic motivation, serves as an effective approach to enhance student learning experiences.

Keywords: Adsorption isotherm; Learning experience; Project-Based Learning

Introduction

Surface chemistry is the study of phenomena that occur at the interface between two phases of a substance. Surface chemistry studies several concepts namely surface tension and adsorption. The phenomenon of surface tension arises because of an imbalance of forces experienced by the liquid molecules that are on the surface (Somorjai, 2010). Adsorption is a process that occurs on the surface. Adsorption is the event of settling several gases on the surface, for example, contact that occurs from a gas or solution on a metal. The interactions that occur will cause the properties of the metal to be modified or changed. The gas or solution that is attracted to the metal surface is called the adsorbate, while the metal surface is called the adsorbent. According to the strength of the interaction, there are 2 types of the adsorption, namely physical adsorption and chemical adsorption (Birdi, 2010). The adsorption process can be studied by knowing the surface composition of the adsorbent, for example by X-ray spectroscopy. The adsorption process can also be studied by measuring the adsorption intensity of an adsorbent. The adsorption intensity of an adsorbent can be measured by measuring the concentration of the adsorbate before and after treatment. By changing the factors that affect the adsorption ability, we can study the things that affect the adsorption process, which means it also affects the adsorption process. The adsorption process is expressed as an adsorption isotherm. There are several adsorption isotherm models, namely the Langmuir, BET, Freundlich, and Temkin isotherm models (Pashley & Karaman, 2004).

Surface chemistry course is one of the compulsory courses that must be taken by semester 5 undergraduate students of the Chemistry Education Department,

How to Cite:
Pamenang, F. D. N., Wibowo, R. S., & Marlinda, F. B. (2024). Project-Based Learning in Teaching Adsorption Isotherm: The Implementation and Students' Opinion. *Jurnal Penelitian Pendidikan IPA*, *10*(4), 1941–1949. https://doi.org/10.29303/jppipa.v10i4.5543

Universitas Sanata Dharma. This course is a theoretical course that has not been integrated with practical work in the laboratory. Actually, practical activities are very important in science education. Practical work can help students understand concepts in depth because, through experiments, students get evidence based on the theories they have learned (Sotiriou et al., 2017). Practical work in the laboratory is important activity because it can support the creation of learning that can be actualized in real terms. According to Indriyani et al. (2022), laboratory experiments are part of teaching which aims to provide opportunities for students to test and implement in real situations what has been obtained theoretically.

Many studies have shown that practical work provides many benefits, including increased psychomotor abilities in the laboratory and scientific knowledge. Understanding of science concepts and theories also increases (Schwichow et al., 2016). Students who were taught using learning strategies in the laboratory showed better results than students who were taught using the lecture method. Learning methods in the laboratory are more effective. Students learned laboratory skill more effectively and improve their knowledge and confidence, so lecturers should equip students with problem-investigation skills in the laboratory rather than just telling facts about chemical concepts (Towns et al., 2015). Many concepts in chemistry need to be presented in the form of practical work because chemistry is an applied science. Some concepts are difficult to understand if not put into practice. With practical work in chemistry lessons, science becomes easier to understand and fun for them, so this can motivate students to understand chemistry better. Practical work helps students able to collaborate with friends, answer questions, and draw graphs (Shana & Abulibdeh, 2020).

In this research, practical work in the laboratory is integrated with project-based learning. Project-based learning relates to the research-based teaching method which guides students in building concept knowledge by working on important projects and developing actual outputs (Krajcik & Shin, 2014; Brundiers & Wiek, 2013; Torres et al., 2017). Project-based learning (PjBL) is an educational approach centered around the completion of a project as the primary objective. This shifts the dynamics of chemistry learning in the classroom away from a teacher-centered approach to one that emphasizes student engagement and activity. Utilizing project-based learning (PjBL) as an instructional model has the potential to enhance students' abilities in areas like planning, communication, problem-solving, and decision-making. The PjBL methodology proves especially effective when applied to subjects connected to real-life applications, such as science and technology (Subiki et al., 2023). PjBL is a problem-based and student-centered learning that focuses on developing projects (Thomas, 2020).

Krajcik & Shin (2014), identified six characteristics of PjBL, including provocative questioning, focus on learning objectives, role in educational activities, teamwork among students, use of frame techniques, and creation of concrete deliverables. A review by Chen & Yang (2019) analyzes the impact of PjBL and direct teacher instruction on student performance at the primary, secondary, and high school levels. PjBL refers to a learning process in which students engage in full-scale projects and product development. Results showed that PjBL had a better impact on student academic performance than direct instruction (Soffiany & Purbani, 2020). Practicum-based projects provide an increase in student learning outcomes (Khoiri et al., 2023). On the other hand, the use of a project-based practicum can increase creativity in preparing tools and materials, practicum stages, and the quality of practicum results (Ermayanti et al., 2020). Students' participation is improving because of information sharing and discussion.

Therefore, the PjBL method is highly suggested in learning by students and should be implemented in universities as well (Almulla, 2020). The focus of project-based learning is on the learning science of active construction. This process of generating new knowledge allows students to test and implement their ideas in any way they like, cultivating innovation skills. Therefore, there is a need to encourage higher education instructors to use project-based learning. PjBL can be described as a collaborative, inquiry-based teaching method in which students integrate, apply, and build their knowledge as they work together to create solutions to complex problems (Guo et al., 2020). Students must practice such work at school, because future generations will have to overcome global environmental problems. As such, science education must provide students with deeper learning rather than simple memorization of facts; students need the ability to apply their scientific knowledge in situations that require problem-solving and decision-making (Miller & Krajcik, 2019). According to research Lasauskiene & Rauduvaite (2015), lecturer also feels positive effects when applying project-based learning in the form of increasing student competence, good collaboration between lecturers and students, and development of lecturer professional competence.

Based on the findings of the problems above, this research was conducted to improve student academic achievement by applying the project-based learning model with practical work in the laboratory. The purpose of this study was to produce new learning that provides better learning outcomes and at the same time encourages students to get used to learning scientific investigation and observation. The utilization of the PjBL model for learning is not arbitrary. It involves a structured sequence of steps outlined in the PjBL learning model, which are presented in Table 1 as follows.

This study aimed to enhance students' academic performance by implementing the PjBL model. Its primary objective was to assess how the PjBL model influences the learning outcomes of undergraduate students. The advantages of this research include acquiring cognitive knowledge in the field of science and offering alternative teaching methods within the classroom, while also serving as a reference for future research endeavors. Also, this study holds significance as it facilitates a comprehensive understanding of the application of the PjBL model in the realm of teaching adsorption isotherms. This research provides valuable insights into the integration of PjBL within surface chemistry education, specifically focusing on the topic of adsorption isotherms. Moreover, the inclusion of students' opinions and perspectives in this study offers valuable insights into the efficacy of this instructional approach. By comprehending the implementation of PBL and considering students' feedback, this research can serve as a guiding resource for educators aiming to improve the teaching of adsorption isotherms through a more interactive and project-oriented methodology.

Method

This study aims to investigate the implementation of PjBL in adsorption isotherm learning. The research method used in this study was a mixed-method (Creswell & Creswell, 2018). The strategy used in this study was a Sequential Explanatory Design with a scheme that can be seen in Figure 1. Based on the Sequential Explanatory Design scheme above, the explanatory sequential design is a way of collecting data that begins with collecting qualitative data and then proceeding with collecting quantitative data to help analyze the data obtained qualitatively, so that the results of research with this design are descriptive in general. The research starts with qualitative research and continues with quantitative research following an explanatory strategy. The research was conducted at the Chemistry Education Department, Universitas Sanata Dharma Yogyakarta with 12 respondents taking place on May 8, 2023.

The qualitative data for PjBL was collected through classroom observations. These observations captured complex situations that enhance our understanding of the practical aspects of implementing PjBL in real classroom settings. The observations focused on the implementation of PjBL stages within the classroom. These stages encompassed the determination of fundamental questions, development of a project plan, arrangement of a schedule, monitoring both students and project progress, conducting outcome assessments, and evaluating the overall learning experience.

The quantitative instrument used in this research is by using a questionnaire. The data collection technique was carried out by distributing open and closed questionnaires with Google Forms which were distributed online. The questionnaire aimed to find out student perceptions of isotherm adsorption learning with project-based learning. It consisted of four indicators, namely interaction between lecturer and students, learning motivation, material understanding, and implementation of project-based learning.

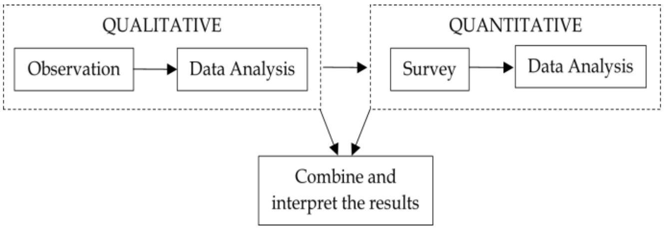

Figure 1. Schematic research design

The quantitative data obtained from the respondent's questionnaire were analyzed by grouping the answers from the respondents based on the questionnaire questions. Then give a score to each answer according to the scoring criteria. Then calculate the total score of the answers to each question. The questionnaire uses the Likert scale where the answer choices are by the contents of the question, namely strongly agree, agree, disagree, and strongly disagree with a score of 4, 3, 2, and 1. Then calculate the percentage score and interpret qualitatively. The formula used to calculate the percentage score for each item is as Question 1.

$$P = \frac{f}{N} \times 100\% \quad (1)$$

Description:
P = score percentage
f = the number of respondents who chose alternative answers
N = total number of respondents

Result and Discussion

This research aims to investigate the implementation of project-based learning in understanding adsorption isotherms and to gather students' opinions regarding the application of this learning model. The findings in this research are based on quantitative data, which includes data collected from practical results and responses obtained from student questionnaires.

Implementation of PjBL and Students' Opinions

This research employs project-based learning, where students are tasked with determining adsorption isotherm models from various adsorption processes involving a specific adsorbent and adsorbate. In this project, students begin by collaboratively addressing essential questions relevant to everyday life in groups. The project-based learning model also received a positive response from students, as indicated by the results of the student response questionnaire.

At the outset of the learning activity, the students are presented with a question. This prompts them to explore different scenarios, formulate hypotheses, devise simple experiments based on each group's ideas, create schedules, design experimental tools and materials, conduct experiments, collect and process data, and present the results, engaging in discussions with their groups in class. The Project-Based Learning model employed in this research unfolds through a series of stages. Initially, participants engage in the process of determining fundamental questions. Subsequently, they progress to designing project plans, followed by the scheduling of tasks. The next stage involves the active supervision of project development. Finally, the participants engage in conducting assessments and evaluations to gauge the effectiveness and outcomes of the project-based learning experience (Almulla, 2020).

Determination of Fundamental Questions

During this stage, the lecturer poses essential questions designed as practical scenarios aligned with the content of the course material. These questions aim to inspire students to tackle problems creatively and innovatively (Zolfaghari et al., 2011). One such question is how to assess the adsorption capacity of an adsorbent. Project-based learning encourages students to be more active, fostering group activities where they can ask questions and share opinions or ideas. Figure 2 shows a significant 58.3% of respondents strongly agree that PjBL enhances students' creativity in project design, while 41.7% believed it fosters increased participation in discussion activities. The students respond to this challenge by identifying adsorbents and adsorbates for their research. Consequently, students are encouraged to formulate hypotheses, which they later validate through experiments or practical activities. Measuring the adsorbate's concentration before and after adsorption allows students to determine the adsorption capacity of the adsorbent used.

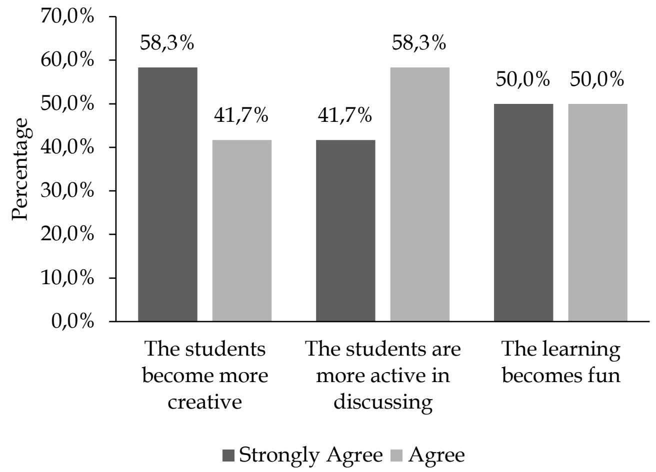

Figure 2. Students' perception on implementation of Project-Based Learning

Designing Project Plans

After students have formulated a hypothesis and devised one or more experiments, they proceed to plan their project by creating a project design. This project design includes the following elements: the project's type, estimated completion time, necessary tools, materials, and data sources. According to the questionnaire results, 58.3% of students planned their projects by gathering information from books, research journals, or the internet as sources for project design. The type of project students create involves practical work aimed at determining the adsorption capacity and adsorption isotherm models of an adsorbent they have identified. The proposed project design is initially reviewed by the lecturer. Table 1, phase 2 displays the project design proposed by the students.

The students presented very creative project designs. Each group initiates their project by selecting the adsorbent and adsorbate to be synthesized. The next step involves planning the project's stages, during which students design experimental procedures for adsorbent synthesis and test its adsorption capacity, including determining the adsorption isotherm model.

Table 1. PjBL Syntax and Aspect

PjBL syntax	PjBL aspect
Phase 1 Determination of fundamental questions (start with essential question)	In phase 1, students initiate their learning journey by exploring fundamental inquiries, which are questions designed to guide them in undertaking activities linked to the science content they will be studying.
Phase 2 Develop a project plan (design project)	In phase 2, students design a project that answers the problem of the adsorption isotherm model. Below are projects designed by students: Adsorption of $CuSO_4$ with eggshell adsorbent, Adsorption of methylene blue with coconut fiber adsorbent, Utilization of pineapple leaf fiber as an adsorbent for methylene blue dyes, Absorption of sengon wood ash biosorbent on Cu(II) ions, Adsorption of acetic acid using activated charcoal
Phase 3 Arrange a schedule (create a schedule)	In phase 3, both students and the teacher collaborate to establish a project timetable for project completion.
Phase 4 Monitoring students and project progress	In phase 4, the teacher monitors project-making activities by paying attention to adsorption experiments carried out by students.
Phase 5 Outcome assessment (assess the outcome)	In phase 5, the teacher evaluates the results of the project that the students have created by paying attention to the resulting adsorption isotherm model and other assessment criteria.
Phase 6 Evaluation of the experience	In phase 6, students and lecturer reflect (evaluate) the activities and results of projects that have been carried out

Arrange a Schedule

In this step, the students prepare a schedule for implementing the project. The lecturer explains the expected duration of the project. In this stage, students refine their critical and strategic thinking abilities by assessing the required tasks for project planning and implementation, ensuring that their projects are completed within the time frame set by the lecturer. Therefore, the implementation of the PjBL model has the most significant impact on students' critical thinking skills at university levels (Bilgin et al., 2015). In the subject category, applying the PjBL model exhibits a substantial effect on both critical thinking skills and creative thinking when employed in science and physics subjects (Hikmah et al., 2023).

Additionally, time allocation for working on the project is determined to enhance its effectiveness and efficiency. Nevertheless, certain students encountered challenges during the project implementation. One notable challenge they faced was the difficulty in locating appropriate research articles. Additionally, some students encountered obstacles in sourcing the right materials for use as adsorbents and adsorbate. These difficulties ultimately led to delays in the project's timeline, causing it to deviate from the originally scheduled timeframe.

Supervise Project Development

At this stage, the lecturer oversees the progress of students' projects conducted in the laboratory. This supervision aims to ensure that the project adheres to the previously prepared plans and to identify and address any obstacles students may encounter during project execution. Monitoring progress is crucial for lecturer to provide additional assistance if needed. Furthermore, students must learn to adhere to their schedules and ensure that everything proceeds smoothly. Lecturer conducts this project implementation monitoring as part of the project evaluation process. The interaction between lecturer and students also provides positive results, with lecturers providing valuable assistance when students encounter project-related difficulties. These positive outcomes are illustrated in Figure 3. The lecturer's role is crucial in this learning process, with 75% of students stating that lecturer provided assistance and guidance when they encountered project-related difficulties. According to the questionnaire results, 50% of students indicated that their lecturer encouraged active participation in group activities, promoting interaction through questions and idea sharing among students. Richardson & Mishra (2018), state that educators who employ creativity in their teaching methods can foster students' learning potential and enthusiasm. The research show that creative teaching as the capacity to actively involve students in the learning process, address challenges in teaching situations, and incorporate innovation or novelty into their instructional approaches (Ismayilova & Laksov, 2023).

Conduct Assessment

During this stage, students present the outcomes of their projects, and the lecturer assesses them. The lecturer evaluates both the process and the final results of the project, offering feedback, and reinforcement to students.

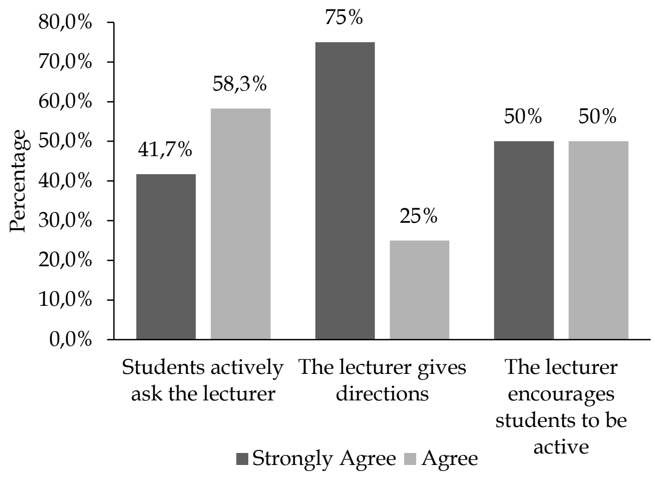

Figure 3. Students' perception on interaction between lecturer and students

Evaluate the Experience

Evaluation takes place after the completion of project-based learning. The experience gained from the projects undertaken by students deepens their understanding of adsorption learning.

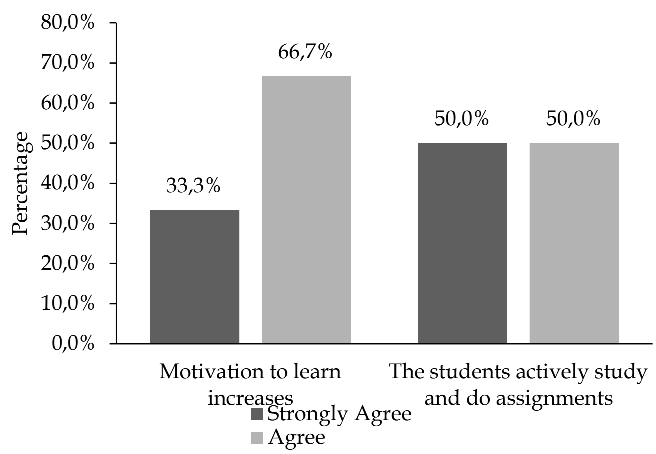

Figure 4. Students' perception on learning motivation

The students also noted that learning becomes engaging for students. Figure 2 demonstrates that learning through PjBL creates an enjoyable classroom atmosphere, with 50% of students strongly agreeing with this. Figure 4 reveals that 66.7% of students feel motivated to learn, resulting in increased activity and creativity in their assignments compared to before. Aligned with Chintya et al. (2023), the PJBL model is not solely about expressing opinions; it also involves problem-solving by assigning projects, aiming to enhance students' creativity and foster their creative thinking abilities (Zatya et al., 2022; Chintya et al., 2023). Lastly, Figure 5 shows that 66.7% of students believe the PjBL model helps them understand and comprehend the flow of adsorption experiments well, particularly in determining contact time, adsorbent mass, and adsorbate concentration for adsorption practicum.

Students express satisfaction and enthusiasm for learning about adsorption isotherms using the PjBL model, which has been implemented. They appreciate how the projects and discussions enhance their understanding of the material. According to Rijanto & Iqrammah (2020), their research found that classes utilizing the PjBL learning model tend to achieve superior average results compared to those not using this model. This finding is consistent with the outcomes of Subiki et al. (2023), which concluded that the adoption of PjBL can lead to enhanced student learning outcomes. The study outcomes revealed that project-based learning had a substantial positive impact on students' learning outcomes, academic achievement, affective attitudes, and thinking skills, particularly in comparison to the conventional teaching model (Zhang & Ma, 2023). Also, the research results indicate that these findings may lead to the conclusion that project-based learning (PjBL), supported by e-worksheets, has a positive impact on students' learning outcomes in science (Aprida & Mayarni, 2023).

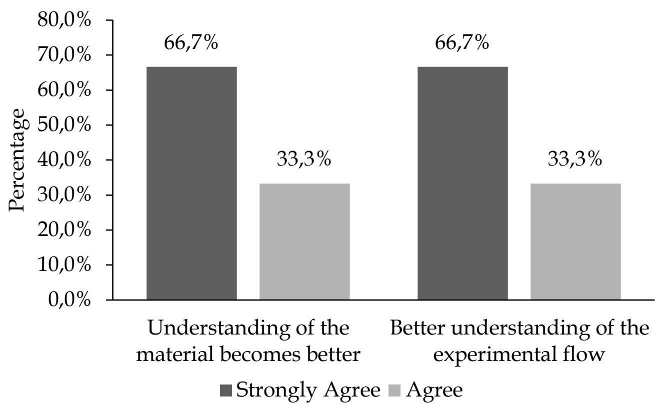

Figure 5. Students' perception on material understanding

Based on Yuli's research, this learning model also enhances students' cognitive learning outcomes across various aspects, including average scores, lowest scores, highest scores, the number of students who complete the learning objectives, and the percentage of overall learning completion. The average posttest score showed an increase of 29.38%. This demonstrates that the PjBL learning model, incorporating both process and product differentiation, effectively improves collaboration skills and cognitive learning outcomes among students (Efliana et al., 2022; Nestiyarum & Widjajanti, 2023).

Consequently, students express a desire for project-based learning to be integrated into other course materials. The PjBL model's curriculum comprises elements such as simplicity of execution, the capacity to address everyday challenges, and student involvement. Students share a viewpoint that aligns with the characteristics of PjBL model students, encompassing the encouragement of active skills, critical thinking, effective communication, collaboration, ease, enjoyment, and the promotion of student learning accomplishments (Masbukhin et al., 2023; Monika et al., 2023). Two students also provided opinions regarding the implementation of PjBL.

S04: "In preparing and executing projects, I can actively engage in discussions with my group of friends to carry out our planned tasks. Additionally, seeking information from various sources has expanded my knowledge about adsorption. Through the project, I've gained a deeper understanding of the principles of adsorption because I was directly involved in the learning process."

S09: "The experience of conducting adsorption practicums has significantly improved my comprehension of the course material. Preparing the project was enjoyable as it allowed us to discuss and propose our ideas. During the practicum, we gained a more profound understanding of the steps involved in determining concentration, and adsorbent mass, and establishing the isotherm model."

Engaging in project-based learning exercises can cultivate students' creativity and self-awareness, thereby making their acquired knowledge more meaningful (Setiawan et al., 2023). Consequently, students tend to retain this knowledge for longer periods as they actively construct their own understanding. Additionally, the PjBL model fosters increased collaboration among peers and enhances scientific communication between students and lecturer, promoting scientific engagement and making students more active participants in the classroom.

Conclusion

The utilization of the project-based learning approach is a strategic method employed to enhance student performance within the adsorption isotherm model, with the goal of achieving improved learning outcomes. The results of data analysis allow to conclude that positive feelings of students while doing project-based learning, including interaction with the lecturer, learning motivation, understanding of the material, and the implementation of project-based learning, contribute to favorable conditions for adsorption isotherm learning. This learning process allows students to explore and accomplish their ideas in the way they want, which supports their ability to innovate. Therefore, we advocate for the promotion of project-based learning among higher education instructors.

Acknowledgments

The author expresses gratitude to all individuals who contributed to the completion of this article. It is the author's hope that this article will be of value in the realms of education and science, particularly in the context of chemistry education.

Author Contributions

Conceptualization; methodology; data analysis; writing-review and editing, F. D. N. P; data collection, R. S. W and F. B. M. All authors contributed to the article and approved the submitted version.

Funding

This research was funded by the Research and Community Service Institutions in Universitas Sanata Dharma, Yogyakarta, Indonesia.

Conflicts of Interest

In this study, none of the authors have any conflicts of interest. The researchers' sole aim is to contribute to the advancement of education by sharing the findings, ultimately benefiting the readers.

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