Analysis Of Obstacles To Students' Science Process Skills In Learning Basic Physics II

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Abstract

This study aims to analyze the barriers to students' science process skills in the Basic Physics II course, with a particular focus on optical instrument topics. The research employed a qualitative descriptive approach involving physics education students who were enrolled in the Basic Physics II course. The sample was selected using a purposive sampling technique based on the following criteria: active students who had participated in both lectures and optical instrument laboratory activities. Data were collected through observations, interviews, and analysis of laboratory report documents. Data analysis was carried out using the Miles and Huberman model, which includes data reduction, data display, and conclusion drawing. The findings indicate that students encountered several barriers related to their science process skills. The most significant barrier was the skill of measuring the angle of incidence and the angle of refraction (74%), followed by difficulties in interpreting experimental data (70%), observing refraction phenomena (65%), and formulating conclusions (68%). In addition, students also experienced challenges in analyzing variable relationships (61%) and preparing systematic laboratory reports (57%). Interviews revealed that some students tended to follow the lecturer's instructions without independently analyzing the variables, and many still viewed laboratory reports merely as a formality. The novelty of this study lies in its specific focus on analyzing barriers to students' science process skills in the context of optical instrument learning, thereby providing a meaningful contribution to mapping the challenges in optics education

1. Introduction

Science education in higher education plays a strategic role in equipping students with scientific thinking skills, analytical abilities, and systematic problem-solving competencies (Jamaludin et al., 2023; Taufiqurrahman, 2023). In the global context of the twenty-first century, science process skills have become essential competencies for students, as they are directly related to the ability to understand concepts, conduct experiments, and draw conclusions based on empirical evidence (Mahrunnisya, 2023; Redhana, 2019).

Therefore, the quality of science learning, particularly in Basic Physics courses, greatly determines the extent to which students are able to develop their scientific skills.

Basic Physics II is one of the key components of the science education curriculum in higher education (Doyan et al., 2022; Ningsi & Nasih, 2020). This course not only provides theoretical foundations but also requires students to connect physics concepts with real-world phenomena through experimental activities. One of the important topics in Basic Physics II is optical instruments, which often serve as an initial context for training students' abilities to observe, measure, interpret data, and formulate scientific principles. Thus, science process skills are highly relevant to be fostered through learning in this topic.

Science process skills encompass basic abilities such as observing, classifying, measuring, interpreting, and predicting, as well as integrated skills such as designing experiments, controlling variables, and analyzing data (Syaifullah et al., 2024; Yunita & Nurita, 2021). However, in actual learning practices, students frequently encounter various obstacles in mastering these skills (Nadia Natalia Simamora et al., 2022; Zahra, 2022). These challenges may arise from limited conceptual understanding, difficulties conducting experiments, and lack of experience in interpreting observational data. If these barriers are not identified and addressed, they may negatively affect both the quality of the learning process and students' learning outcomes.

The topic of optical instruments is considered one that requires strong science process skills (Purwaningtias & Putra, 2020). Learning this topic involves abstract concepts, measurements using optical devices, and the interpretation of complex physical phenomena (Nuning Tiastiti et al., 2024; Retnani et al., 2024). Students often face difficulties, such as understanding Snell's law, determining the critical angle, or correctly interpreting refraction experiment data. Therefore, optical instruments provide an appropriate context for examining the challenges students face in mastering science process skills.

Previous studies have shown that students' science process skills remain in the low to moderate category. Many students struggle with interpreting data and designing simple experiments (Sari et al., 2023). In optics learning, particularly in refraction materials, students tend to memorize formulas without understanding the underlying scientific processes. Limited laboratory facilities and teacher-centered learning methods further hinder the development of science process skills (Ningsi & Nasih, 2020). However, studies that specifically analyze students' barriers within the context of optical instruments remain relatively limited.

This study offers novelty by focusing on analyzing the barriers experienced by students in science process skills on the topic of optical instruments, rather than merely measuring their skill levels. Thus, this research not only captures students' competency levels but also identifies specific factors that hinder the mastery of these skills in the Basic Physics II course. The findings are expected to provide deeper insights into the challenges faced by students and serve as a foundation for designing more effective learning strategies.

The urgency of this study lies in the need to improve the quality of Basic Physics II learning through the strengthening of students' science process skills. By identifying the barriers encountered by students, lecturers can formulate more appropriate pedagogical approaches, utilize suitable learning media, and enhance laboratory practices to better support the development of scientific skills. The purpose of this study is to analyze the barriers to students' science process skills in the Basic Physics II course, particularly in the topic of optical instruments, so that applicable recommendations for improving higher education learning can be obtained.

2. Research Methods

The subjects of this study were students of the Physics Education Study Program at Universitas Jambi who were enrolled in the Basic Physics II course. The target population consisted of students who had received instruction on optical instruments through lectures and laboratory activities. The selection of subjects was carried out using purposive sampling, namely the deliberate selection of participants based on specific criteria:
(1) active students who had taken the Basic Physics II course, (2) participated in optical-related laboratory activities, and (3) were willing to serve as research respondents.

The research procedures were carried out through several systematic stages: (1) Preparation stage, including the development of research instruments, identification of subjects, and coordination with the course instructor; (2) Data collection stage, consisting of observations during lectures/laboratory sessions, in-depth interviews with students, and the collection of documents related to learning outcomes; (3) Data analysis stage, which included data reduction, data display, and drawing conclusions regarding the barriers to science process skills; and (4) Reporting stage, involving the preparation of the final research report.

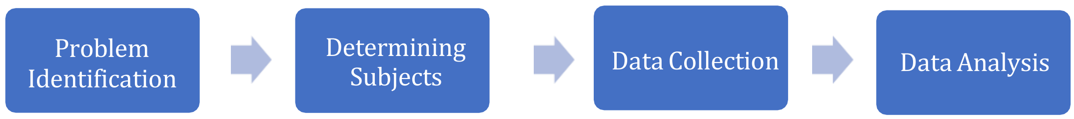

Figure 1. Research Procedure

The research instruments consisted of observation guidelines, semi-structured interview guidelines, and documentation of students' laboratory report results. Observations were conducted to examine students' activities during the learning process and laboratory sessions on optical instruments. Interviews were carried out to explore students' experiences, perceptions, and challenges in mastering science process skills (Damayanti et al., 2024). Meanwhile, documentation was used to review laboratory records, student reports, and the learning materials employed. Triangulation techniques were applied to enhance the validity of the data by combining observations, interviews, and document analysis.

Data were analyzed qualitatively using the Miles and Huberman model, which consists of three main stages (Baltacı, 2017): (1) Data reduction, namely selecting, focusing, and simplifying data obtained from observations, interviews, and documents; (2) Data display, which involves organizing data into descriptive narratives, tables, and matrices to facilitate understanding; and (3) Conclusion drawing and verification, namely formulating research findings regarding the barriers to students' science process skills in the Basic Physics II course, particularly in the optical instruments topic.

3. Result and Discussion

Based on observations, interviews, and the analysis of students' laboratory report documents, it was found that students encountered various barriers in mastering science process skills in the optical instruments topic. These barriers emerged not only in conceptual aspects but also in technical and methodological aspects during laboratory activities. Among the 25 students participating in the study, most reported difficulties in understanding Snell's law, determining the angle of refraction, and connecting measurement results with existing theoretical concepts. In addition, several psychomotor challenges were identified, such as operating optical instruments, accurately measuring angles, and managing limited laboratory time, which prevented students from conducting experiments optimally. The following table presents the main findings related to the barriers in students' science process skills:

Table 1. Analysis of Students' Barriers in Science Process Skills

No	Aspect of Science Process Skills	Types of Barriers Encountered by Students	Percentage of Students Experiencing Barriers
1	Observing phenomena	Difficulty identifying detailed changes in the direction of light as it passes through different media	65%
2	Measuring	Inaccuracies in measuring the angle of incidence and angle of refraction using optical instruments	74%
3	Interpreting data	Errors in interpreting the relationship between the angle of incidence, angle of refraction, and Snell's law	70%
4	Analyzing variable relationships	Difficulty determining independent, dependent, and controlled variables in refraction experiments	61%

5	Drawing conclusions	Tendency to copy theoretical explanations without relating them to the experimental data obtained	68%
6	Reporting results	Laboratory reports were not systematic, often only containing numerical tables without indepth analysis	57%

The table above shows that the greatest barrier experienced by students lies in the measuring aspect (74%), where most students were not sufficiently meticulous in using optical instruments and faced difficulties in accurately determining the angle of incidence and the angle of refraction. Other significant barriers emerged in the aspects of interpreting data (70%) and observing phenomena (65%), indicating that students have not fully understood the connection between conceptual knowledge and observational results.

In addition, students also faced challenges in drawing conclusions (68%), as many tended to reproduce theoretical explanations from textbooks without analyzing the experimental data they had collected. Barriers in analyzing variable relationships (61%) and reporting results (57%) further indicate that some students are still lacking in systematic scientific thinking.

These findings reinforce previous studies suggesting that students' science process skills remain in the low to moderate category, particularly in optical experiments. The results highlight the need for learning strategies that place greater emphasis on strengthening laboratory skills, providing guidance in data interpretation, and incorporating interactive learning media that can concretely visualize optical phenomena.

Interviews were conducted with 10 students selected through purposive sampling. The interview results revealed that the barriers to students' science process skills stem not only from limited conceptual understanding but also from insufficient laboratory experience and minimal technical guidance during experiments. The following section summarizes the key findings from the student interviews:

Table 2. Results of Student Interviews

No	Interview Question	Analysis of Students' Responses	Researcher's Interpretation
1	What is your main difficulty when conducting optical instrument experiments?	Difficulty measuring the angle of incidence and the angle of refraction; the instruments are small and the results are often inaccurate.	Technical barriers in measurement skills.
2	How do you understand the relationship between experimental results and Snell's law?	Students remain confused; experimental results often do not match the formula, causing uncertainty.	Conceptual barriers in interpreting data.
3	Do you experience difficulties in designing experimental steps or determining variables?	Students tend to follow the instructor's guidelines directly and are rarely asked about variables.	Barriers in independent scientific thinking, particularly analyzing variabl e relationships.
4	What is your experience in preparing laboratory reports on optical instruments?	Reports mostly consist of filling in tables and writing brief conclusions; sometimes copied from peers.	Barriers in reporting results systematically and originally.

5	In your opinion, what could help reduce difficulties in this practicum?	Using simulations or videos might make it easier to understand the material before practicing.	Suggested solution: using interactive media to clarify abstract phenomena.

Based on interviews with ten students, it was found that the barriers to science process skills in the optical instruments topic arise from multiple aspects, both technical and conceptual. Technical barriers were especially evident in the skill of measuring the angle of incidence and the angle of refraction. Most students reported experiencing difficulties when operating optical instruments, resulting in inaccurate measurement outcomes. Conceptual barriers emerged when students were required to connect experimental data with Snell's law, as the results often did not align with the theoretical formula they understood. This discrepancy led to confusion and doubt during the learning process.

In addition, students demonstrated limited ability in designing experimental procedures and determining variables. Most respondents stated that they simply followed the instructor's or laboratory manual's instructions without fully understanding the importance of identifying independent, dependent, and controlled variables in scientific investigations. This barrier indicates a lack of independent scientific reasoning. Regarding report writing, students admitted that their laboratory reports were prepared merely as a formality, consisting mostly of data tables and brief conclusions without deeper analysis. Some even mentioned copying reports from peers, which highlights weaknesses in scientific communication skills.

The findings indicate that students experience considerable challenges in science process skills when studying optical instruments. The most prominent barriers lie in measuring the angle of incidence and the angle of refraction, as well as interpreting experimental data. Students often encounter difficulties using optical instruments accurately, resulting in measurement outcomes that do not match theoretical expectations. Furthermore, they struggle to connect empirical data with Snell's law, suggesting that their scientific reasoning has not developed optimally. This implies that students' basic and integrated science process skills are not yet fully trained.

Previous studies by Hidayat et al. (2020) also reported that students tend to lack independence in analyzing experimental variables and preparing laboratory reports. Laboratory activities are often treated as routine tasks to fulfill course requirements rather than as opportunities to develop scientific thinking skills (Alatas & Solehat, 2022; Fedorov & Mikhaleva, 2020; Hafizah & Nurhaliza, 2021). Laboratory reports are typically limited to brief descriptions without in-depth analysis, and many students admitted copying from peers (Loudon, 2019; Midway et al., 2020; Navarro et al., 2024). These conditions show that the barriers students face are not only cognitive but also related to scientific attitudes and science communication skills. Such barriers highlight the need for instructional strategies that emphasize authentic scientific experiences accompanied by more structured guidance.

The findings of this study are consistent with several previous research results. Students frequently experience difficulties in interpreting data and designing simple experiments in optics-related topics (Purwaningtias & Putra, 2020). In learning optical instruments, students tend to memorize formulas rather than understand the underlying scientific processes (Nuning Tiastiti et al., 2024). Thus, this study reinforces earlier evidence that students' barriers in mastering science process skills are complex, encompassing conceptual, technical, and methodological aspects.

The novelty of this research lies in its specific focus on analyzing students' obstacles in developing science process skills in the context of optical instruments. While previous studies mostly explored the level of students' science process skills or the effectiveness of certain teaching methods, this study emphasizes the identification of hindering factors encountered by students during actual learning practices. Therefore, it provides a new contribution by mapping these barriers in detail, which may serve as a basis for designing more targeted pedagogical interventions.

The findings of this study have important implications for instructional practices in the Basic Physics II course.

Lecturers may utilize these results to design more interactive laboratory-based learning strategies, integrate simulation media to visualize abstract phenomena, and offer more intensive guidance during laboratory activities. However, this study has a limitation in that it involved a relatively small number of participants from a single institution; therefore, the generalizability of the results remains limited. Further research with a wider scope and employing mixed-methods approaches is recommended to provide a more comprehensive understanding of the barriers to students' science process skills in optics.

4. Conclusions

This study demonstrates that students continue to face various obstacles in mastering science process skills in Basic Physics II, particularly in the topic of optical instruments. These obstacles include technical aspects, such as inaccuracies in measuring the angle of incidence and angle of refraction; conceptual aspects, such as difficulties connecting experimental results with Snell's Law; and methodological aspects, including limited ability to analyze experimental variables and prepare systematic laboratory reports. In addition, students' scientific attitudes remain underdeveloped, as indicated by their tendency to treat laboratory work as a mere formality without conducting in-depth analysis. These findings indicate that the barriers to students' science process skills are multidimensional and require more innovative, participatory, and experience-based learning strategies. Accordingly, this study contributes by mapping the inhibiting factors of science process skills, which may serve as a foundation for curriculum refinement, development of instructional media, and improvement of physics practicum quality in higher education.

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