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Exploring the Implementation of Modern Physics Practicum to Enhance the Science Process Skills of Indonesian Physics Education Students

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ABSTRACT

Purpose – This study aims to analyze the perceptions of Indonesian physics education students in the implementation of modern physics practicums on students' science process skills.

Design/methods/approach – The type of research used is descriptive research with a quantitative approach. The method used is a questionnaire survey to obtain data. Respondents in this research amounted to 34 respondents, with a purposive sampling technique. The data were analyzed using descriptive statistical techniques by classifying data in class intervals and frequencies, with each interval calculated to determine the distribution of data and converted into percentage form.

Findings – The results of the study showed that Indonesian physics education students have a positive perception of modern physics practicums with 80% agreeing. The level of self-confidence in implementing SPS is still not stable with 41% of students feeling hesitant. For changes in knowledge and skills, 32% of students gave a negative response to the change. This shows that there is still doubt among students about the effectiveness of practicums in improving SPS.

Research implications/limitations – Modern physics practicum provides a fairly good experience in improving students' understanding and confidence in SPS, but there are still challenges such as instability of confidence and doubts about its effectiveness. Therefore, evaluation of learning methods and further research are needed to explore the application of SPS in various institutions and analyze the factors that influence low student confidence.

Originality/value – These findings suggest that although physics education students have positive perceptions of the lab, the instability of their confidence in science process skills indicates the need for more effective learning strategies to improve practical competence. The uncertainty in changes in students' knowledge and skills highlights the need for further evaluation of the design and implementation of the lab in order to truly strengthen science process skills optimally.

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Introduction

Student learning outcomes are an important factor influencing the diversity of thinking skills. The academic value obtained by students can be seen from their learning outcomes. One of the factors that influences student academic grades is the teaching and learning process. The teaching and learning process by lecturers or teachers influences student learning outcomes. Therefore, lecturers or teachers always try to carry out quality learning mechanisms so that students can achieve the highest learning outcomes.

One factor influencing student learning outcomes in teaching physics is a complete set of practicum media to support teaching activities and accentuate the process aspects of the need for practicum implementation in physics. This can support psychomotor, cognitive, and affective abilities (Sunardi & Suchyadi, 2020). In addition, practicum activities have an important role for students, especially for prospective physics teacher students. Practical activities for prospective physics teacher students can foster determination to continue learning. Thus, students are not only able to apply science but also can apply the material in everyday life (Puspitasari, et al., 2020).

Government Regulation No. 19/2005 Articles 42 and 43 concerning National Education Standards (SNP) states that laboratories are important facilities in national education standards that support the efficiency and quality of learning, with good facilities positively impacting the teaching and learning process. Then, at the university level, especially in physics study programs, modern physics courses are classified as fundamental because they are often considered complicated and abstract by students (`Ardhuha et al., 2019). Submaterials in modern physics are the concepts of quantum mechanics, core physics, and relativity, which are highly complex (Irvani et al., 2024). This is not only needed in conventional learning but also for practicum activities. In modern physics, practicum is an important component to help students understand complex physics concepts with a model of solving everyday life (Whitcomb et al., 2021).

In modern physics learning, students need SPS because it can encourage students to be active and have a sense of responsibility in the learning process (Wilujeng & Rohman, 2021). Students who master SPS are useful in their efforts to understand and solve problems with scientific methodology. That way, students are not only required to think critically, innovatively, and analytically when applying scientific knowledge in everyday life but also to be able to adapt to current technological advances (Anita, 2022). SPS can also increase student creativity (Bahri et al., 2021)in everyday life.

SPS activities involve applying scientific strategies to master and improve science skills and discover the latest knowledge in science (Hartati et al., 2022). In addition, the science process skills approach in physics learning is inspired by how scientists make observations and research. This reflects how a scientist develops scientific knowledge through systematic observation (Rahmah et al., 2019).

SPS has several main characteristics of scientific attitudes. First, it encourages students' curiosity about phenomena in the surrounding environment. Second, it fosters an attitude of interpretation about the cause-and-effect relationship in every event. Third, it fosters an open mindset to all possibilities (Ariyansyah & Nurfathurrahmah, 2022). Indicators often appear in SPS during practicum, such as asking questions, observing, planning experiments, and conducting experiments that show the application of Science Process Skills in the practicum (Fitriana et al., 2019). In addition, expertise in classifying and categorising is one of the Science Process Skills.

Science Process Skills help students develop a deeper understanding of modern physics phenomena through practicum. Students with good SPS are more likely to understand modern physics concepts (Belga, 2022)successfully. Implementing a modern physics practicum cannot be separated from challenges such as limited equipment, complicated experimental procedures, and students' difficulty analyzing data (Sukenti, 2021). In addition, students' perceptions of the difficulty of practicum can affect their motivation and learning outcomes during practicum activities (Nicol et al., 2022).

While several studies have evaluated the effectiveness of practicum in modern physics learning, there is still a lack of understanding regarding the relationship between students' perceptions and their development of SPS in the context of modern physics practicum. In addition, we also need to understand students' perspectives to improve the design and implementation of the physics practicum and make it more effective. Students often have low confidence in modern physics experiments, especially because the materials and equipment are complex. This condition can help students develop their SPS because confidence is important in experiment-based learning.

Based on this background, this study aims to analyze students' perceptions and development of science process skills in modern physics practicum activities. The results are expected to provide useful insights to improve the effectiveness of modern physics practicum and optimize the development of students' SPS in the context of advanced physics learning. In addition, this research is also expected to guide teachers and educators in designing effective curricula and teaching methods that develop cognitive understanding and practical skills with current technological knowledge.

Literature Review

1. Modern Physics

Modern Physics is one of the subatomic particles tested by the reaction of matter and energy. In modern physics, the subatomic head runs at high speed (Noer & Dayana, 2021a). Micro-scale or atomic scale is a difference that moves quickly when approaching light. Einstein formulated modern physics with the relativity equation (Kurnia, 2021). Einstein is considered the first researcher of modern physics with Max Planck. From this discovery, the concept of modern physics is one of the sources that help discover technological developments. Technology in everyday life includes computers, cell phones, satellites, and medical equipment (CT scans, MRIs, etc..)

The development of modern physics from the classics stems from the first discovery of "The Ultimate Theory." James Clark Maxwell revealed that the constants of physics could be predicted. Still, in reality, the physics theory cannot be predicted in contrast to Albert Einstein, who revealed that an object could move at an extreme speed (Djudin, 2021). This is included in the theory of relativity, which explains the physical formulation of the acceleration of the motion of objects near light; this is classified as a special theory of relativity; the theory of relativity itself is divided into two, namely the theory of general relativity and the theory of special relativity. General relativity discusses space and time in a single gravity (Noer & Dayana, 2021b). Relativity theory is at the heart of classical physics. The special theory of relativity has no special form in electromagnetics. The energy-momentum in spacetime is a key concept in the speed of light in the special relativity f(Lumbangaol et al., 2023).

Over time, Maxwell's classical theory does not discuss the emergence of the era of quantum theory that discusses black body radiation. So, it was continued by Max Karl Ernest Ludwig Planck, who suggested a black hole energy package. The findings were reposted by Einstein, who concluded that light is a particle. Apart from Max and Einstein, one more scientist shares his opinion, namely Arthur Compton, who states that light has momentum (Djudin, 2021). The discovery is often called the Compton effect, proven by light that functions as a wave and momentum. This results in interactions between photons and electrons, which results in changes in the wavelength of light (Amalia, 2020). Compton's concept formed the basis for the idea of particle-wave dualism, which is a fundamental aspect of modern physics.

2. *Science Process Skills*

Science Process Skills are one of the scientific tools scientists use to conduct scientific exploration. The Science Process Skills learning approach is structured in the hope that students can find facts and build concepts and theories in the learning received. Thus, Science Process Skills can be used to increase students' cognitive development because not only learning theory but students also interact with each other (Bahri et al., 2021). Students are invited to contribute to the scientific learning process activities. SPS is one of the skills to master scientific phenomena. Skills are needed to acquire, apply, and develop science concepts, principles, and theories (Iqbal et al., 2022).

According to Murniati et al. (2021) SPS, knowledge can be developed by applying methods, science, and development. They relate to interconnected psychomotor, cognitive, and affective skills in discovering and understanding concepts. SPS can help students, especially those directly involved, to observe real issues, experiment, collect data, and draw conclusions carefully (Yanti et al., 2020). There are eleven indicators of SPS: observing, classifying, interpreting, predicting, communicating, formulating hypotheses, planning experiments, using tools and materials, doing experiments, asking questions, and applying concepts (Suja, 2023). Meanwhile, Rahmiyani et al. (2024) there are six indicators of SPS: observing, interference, measuring, communicating, predicting, and classifying.

Observation skills are basic skills in an observation. When observing using the skills of the five senses, such as smell, sight, hearing, taste, and touch. Students can utilize the five senses to analyze observational skills as much as possible (Putri, 2019). Interference skills help you draw conclusions and gain a new understanding and knowledge (Irmayadi et al., 2020). Interference skills have an important role in measuring the level of student understanding (Putri, 2019). Communicating skills are activities to express the results of observations (Suja, 2023). Prediction skills are skills used to predict a future event by looking at the occurring phenomena. The last is the ability to classify, the ability to classify an object that is observed by comparing similarities and dissimilarities in an object.

3. *Physics Practicum*

Physics practicum is one of the activities that can foster knowledge and skills and positively impact students. With a physics practicum, students can explore knowledge by developing skills in broadening the concept of physics theory. In addition, physics practicum can foster a confident attitude of students in overcoming the tasks given (Panis et al., 2024). In addition, practicum has an important position because students can have the opportunity to prove and apply the theory to everyday life. Practical

activities can be carried out in an open space or a laboratory. Practicum is used to conduct research, proof, and other activities with adequate facilities (Fitriningsih, 2019).

In practicum activities, students will also make a report containing the observations' results to learn to conclude the report. Practical activities aim to understand theory and practice. In the practicum, students will get several benefits. Namely, students feel trained in increasing knowledge and skills, practicum activities can prove a theory, and students can appreciate the knowledge and skills they already have (Rahmayani & Fadly, 2022). With the experience, students will easily understand the concept of material. So, practicum methods, especially in physics, can be very effective in helping students understand concepts (Nuai & Nurkamiden, 2022).

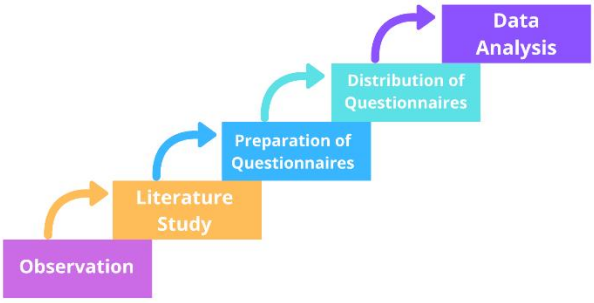
Methods

1. General Background

This research method uses a survey. According to Kusumastuti et al. (2020)the, survey research utilizes a questionnaire as its research instrument to collect information from a sample. The type of survey research used is a cross-sectional survey, a method for collecting data at a certain time, in the modern physics practicum. This survey research is conducted by observing the research subjects once and does not involve follow-up on the research subjects (Lapkin et al., 2012). Research with questionnaires can minimize researcher manipulation because it is in the form of structured question leaflets that respondents fill in. This research method identifies and analyses student perceptions of science process skills developed during modern physics, to achieve these objectives, systematic and structured steps are required in data collection and analysis. The included flowchart illustrates the main stages in this research, from planning to analyzing the results. The following is a general flowchart of the research.

Figure 1

General Research Flow Chart



The research flow began with observing the campus environment and gathering data to gain an initial understanding of the implementation of the modern physics practicum, while also examining how students engage with experiments and apply physics concepts. This stage also aids in designing instruments relevant to the practicum context. Furthermore, a literature study was conducted to deepen the understanding of theories related to science process skills and the physics practicum. This literature review provides a solid theoretical foundation for developing research instruments and assessing previous studies on the topic under investigation. After the

literature review, the next step was to prepare a questionnaire measuring students' perceptions of the science process skills acquired through the modern physics practicum. The questions were organized around scientific skills such as experimental ability, data analysis, and scientific decision-making. Once the questionnaire was prepared, it was distributed to students participating in the practicum to collect quantitative data on their perceptions.

After preparing the questionnaire, it was distributed to students who participated in the practicum to collect quantitative data on their perceptions. The questionnaire was developed using a Likert scale with closed statements, employing a range from 1 to 4. The indicators for developing this questionnaire included student perceptions of the modern physics practicum, student confidence levels in performing science process skills, and changes in knowledge and skills before and after the practicum. The questionnaire consisted of 20 closed statements. The final stage in the flowchart is data analysis. The data collected from the distribution of questionnaires were analyzed using quantitative descriptive analysis techniques to outline the results of student perceptions of science process skills. This analysis will provide insight into the effectiveness of the modern physics practicum in fostering students' scientific skills. Conclusions and recommendations will be drawn from the findings of the data analysis to enhance the quality of the practicum in the future.

2. *The Data Analysis Technique*

The data analysis technique used in this research is the quantitative descriptive analysis technique. Descriptive analysis techniques aim to describe a current event's urgent (necessary) needs. In conclusion, descriptive data emphasizes reliable data and is carried out organized. The purpose of the descriptive analysis was to provide an overview of the distribution of scores and patterns of answers that emerged from the questionnaires completed by participants. Data were analyzed using statistical tools such as Excel to calculate the frequency and percentage of each of the three main aspects. Each variable measured describes the level of student perception of skills related to modern physics practicum and scientific process. This analysis will provide an understanding of student's level of involvement and mastery of SPS after participating in the practicum. The results of descriptive analysis will be presented in a graph to facilitate data interpretation. This descriptive analysis will provide clear information about the effectiveness of modern physics practicum in developing students' science process skills.

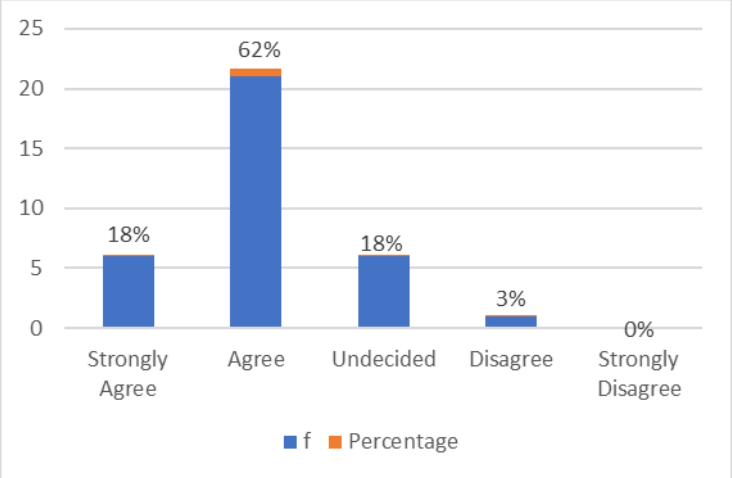
Result

1. Survey Results of Student Perceptions on Modern Physics Practicum

Modern physics practicum is a lecture material, and some of the material is abstract for students. Most students think that this practicum can be a bridge in forming their scientific competence. The growing perception shows that modern physics practicum is not just a routine academic activity but a means to develop thinking skills and understanding of phenomena in their application in everyday life. Students' perceptions of modern physics practicum can be described as a complex experience involving various emotional and cognitive aspects. In addition, some students may feel enthusiastic about carrying out the practicum. However, on the other hand, modern physics practicum can also cause pressure and difficulties that cause stress and discomfort for students. The study results can be seen in Figure 2 in the following bar chart.

Figure 2

Descriptive Picture of Student Perception Percentage N=34



The results of the description analysis of student perceptions of modern physics practicum from Figure 2 found a greater percentage of agreeing to constructive perceptions. In detail, the data shows that 62% of 21 students stated agree, 18% of 6 students stated strongly agree, 18% of 6 students stated disagree, 3% stated undecided, and 0% zero students stated strongly disagree. Thus, the total percentage of students giving positive responses reached 80% (agree and strongly agree). From the results obtained, it can be concluded that even though students face challenges and difficulties in modern physics practicum, most still view practicum as a meaningful learning experience. The results found that most students agreed on concept understanding, fun, and enthusiasm in following each practicum stage.

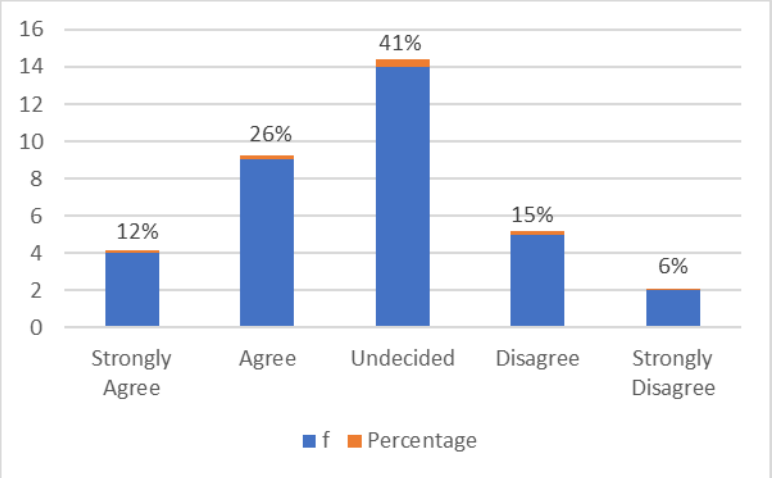
2. Survey Results of Student Confidence Level in Performing Science Process Skills

According to (Cloney et al., 2019) a sense of trust from within, a student can foster a confident attitude of students so that they are enthusiastic about learning. Based on research (Yuliati & Susianna, 2023), students can feel confident when they can understand themselves and know their abilities, so they will have high confidence and

be active in learning activities. In SPS, self-confidence can determine the quality of mastering practicum in the laboratory. Aspects of the ability to collect data, analyze information, master practical tools, make accurate measurements, collaborate with the team, and draw conclusions are a series of competencies that describe student readiness in applying scientific methodology. These SPS are important indicators in shaping students' scientific attitudes and creativity. The study results can be seen in Figure 3 in the following bar diagram.

Figure 3

Descriptive Picture of the Percentage of Self-Confidence Level Students in Conducting KPS N=34



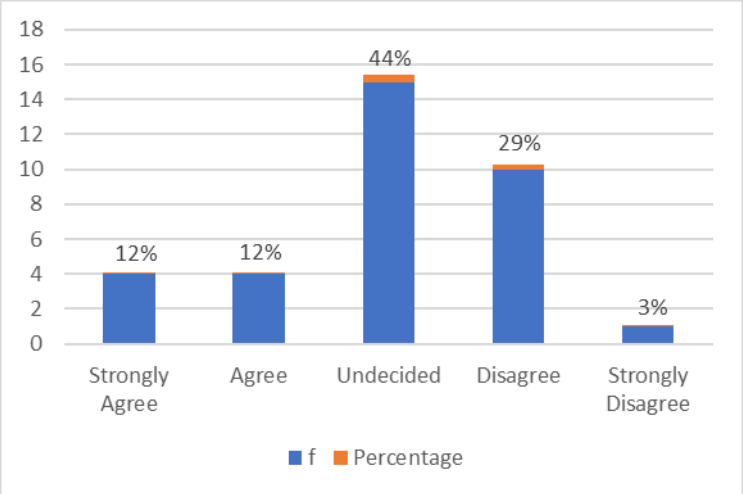
The results of the description analysis of the level of student confidence in performing science process skills from Figure 3 found a greater percentage of hesitation towards the level of student confidence in performing science process skills. This indicates that student confidence in performing the SPS is still less stable. In detail, the data shows that 41% of 14 students said they were undecided, 26% of nine students agreed, 15% of five students disagreed, 12% of four strongly agreed, and 6% of two strongly disagreed. Thus, the total percentage of students giving positive responses reached 38%, but there were still 15% who expressed negative responses. From the results obtained, it can be concluded that students still need more guidance, training, and experience to increase confidence in mastering SPS, especially in aspects of the ability to collect data, analyze information, master practical tools, make accurate measurements, team collaboration, and conclude.

3. Survey Results of Changes in Knowledge and Skills Before and After Practicum

The results of the study Sunardi & Suchyadi (2020) state that there are changes in Science Process Skills and knowledge in students when learning using practicum assistance because the practicum process is related to changes in the surrounding environment. Besides, practicum can also develop thinking skills and teach creativity. Changes in students' knowledge and skills before and after practicum are activities of switching learning methods and adding experiences that allow students to build a deeper understanding of modern physics concepts. Through practicum, students can also develop several aspects, namely aspects of knowledge, the ability to analyze data such as linking theory with practice, and understanding how to analyze data during practicum. Thus, the practicum of modern physics can facilitate students' understanding of the latest research.

Figure 4

Descriptive Figure of Percentage Change in Knowledge and Skills Before and After Practicum N=34



The results of the description analysis of the level of student confidence in performing science process skills from Figure 4 found a greater percentage of doubts about changes in knowledge and skills before and after the practicum. This indicates that changes in knowledge and skills before and after practicum are still less stable. In detail, the data shows that 44% of 15 students stated that they were undecided, 29% of 10 students stated that they disagreed, 12% of four students stated that they strongly agreed, 12% of 4 students stated that they agreed, and 3% with one student stated that they strongly disagreed. Thus, the total percentage of students giving negative responses reached 32%, but there were still 24% who expressed positive responses. From the results obtained, students understand how to analyze modern physics concepts after participating in practicum and can link theory with practice. However, despite the increase, several students still feel doubtful or disagree with some practicum points,

such as science process skills being more improved after the practicum. Practicum provides a good experience linking theory with practice to improve student skills.

Discussion

According to (Muspa & Suwondo, 2020) practicum, devices are experimental tools that are innovatively developed for use in the learning process at school. Practical activities aim to prove and experiment with what is obtained in theory (Candra & Hidayati, 2020). The practicum device consists of practicum tools and practicum modules. Practicum is observing or practicing in the laboratory, then analyzing and making conclusions about the theory on data obtained during the practicum (Nuai & Nurkamiden, 2022). Practicum is important in applying scientific attitudes and developing experience presenting modern physics concepts (Oktavia, 2022), especially in modern physics courses.

Practicum has several advantages, namely training skills, providing opportunities for students to apply and integrate knowledge with skills in practice, proving a theory scientifically, and making students appreciate the knowledge and skills of each other. In addition to the advantages of practicum, it also has several disadvantages, namely inadequate laboratory facilities and lack of creativity from each student (Jumrodah et al., 2023). In addition to the above shortcomings, there are other shortcomings, such as students who do not master how to compile practicum reports, writing that does not comply with language rules and low synthesis skills (Anwar et al., 2020).

Description of the results of data analysis of modern physics practicum activities in physics education students as a whole in this study aims to explore how modern physics practicum improves SPS physics education students, where students or respondents must fill in 20 statements to find out the extent of understanding of modern physics practicum in improving SPS physics education students. Based on the survey results of students' perceptions of modern physics practicum, 62% agreed, and 18% strongly agreed; it can be said that many students responded positively, with a total of 80%. Thus, it can be concluded that even though students face challenges and difficulties in modern physics practicum, most still view practicum as a meaningful learning experience (Rabiudin, 2023).

The study results found that most students agreed on aspects of concept understanding, pleasure, and enthusiasm in following each practicum stage so that practicum activities can improve students' cognitive thinking skills. Practical activities increase students' understanding of concepts compared to when practicum or theory-only fields were given(Nazmi & Rahmasari, 2024). In addition, students can be active in practicum activities with a high sense of enthusiasm (Ardiansyah & Muthi, 2024). So, practicum is included as an effective way to improve student understanding. In addition, many students are more enthusiastic about practicum activities. However, some students may feel less enthusiastic about practicum because they must report the results after practicum.

Based on the survey results of student confidence in Science Process Skills, 41% of students still hesitate to perform SPS. Thus, students still need more guidance, training, and experience to increase confidence in mastering Science Process Skills, especially in aspects of the ability to collect data, analyze information, master practical tools, make accurate measurements, team collaboration, and conclude. Self-confidence can affect the results of student learning achievement. Therefore, students must be confident to master the Science Process Skills (Mulyana, 2021). In mastering practicum tools, an assistant can explain in advance the tools used in practicum activities. Students are expected to pay attention and

actively ask about the function of practicum tools if they are unclear. In team collaboration, students are expected to collaborate to divide tasks when practicum activities begin. However, in reality, many students still do not share equally the tasks of each teammate and only rely on their teammates (Sar'iyyah, 2019).

Based on the survey results of changes in knowledge and skills before and after practicum, 44% of students answered doubtfully. Thus, there are still many students who are hesitant about some practicum points, such as science process skills that are more improved after practicum. Practicum provides a good experience linking theory with practice to improve student skills. In addition, practicum can also increase students' critical thinking, especially in mastering the concept of material. In practicum activities, students will gain experience and motivation to learn modern physics (Arifin et al., 2024). In addition, students can improve Science Process Skills by reading literature related to Science Process Skills to strengthen their understanding (Septi et al., 2022).

Conclusion

Based on the discussion results, physics education students positively perceive practicum because most students, with a percentage of 80%, agree. The confidence level is still unstable in performing SPS, with 41% of students feeling hesitant. For changes in knowledge and skills, 32% of students gave negative responses to these changes. This shows that there are still doubts among students about the effectiveness of practicum in improving their SPS. So overall, modern physics practicum provides a good enough experience to increase students' confidence and understanding of SPS. However, this article also has limitations, especially in the limited number of respondents, and only focuses on one institution, namely physics education students. Another limitation is the lack of in-depth analysis of the factors influencing low student confidence. Therefore, it is recommended that further research be carried out to explore the application of SPS in various educational institutions and examine more deeply the factors that affect students' low self-confidence. Thus. The development of Science Process Skills can be used as a reference to improve the quality of science education.

Declarations

Author contribution statement

The contribution made by the authors in this study is that the first author is responsible for proposing the research idea, collecting data, and analyzing the results. The second author contributed in editing and analyzing the results..

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Data availability statement

All data related to this study can be obtained by sending a message to the following email: 22104050024@student.uin-suka.ac.id

Declaration of interets statement

The authors declare no financial interests or personal relationships that could influence the outcomes of this research.

Additional information

If you have any input into this research, please send a message to the following email: 22104050024@student.uin-suka.ac.id

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