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Analysis of Students' Science Process Skills in Inquiry-Based Learning Assisted by Scaffolding via Cueing Techniques on the Topic of Heat

Manuscript Information

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Abstrak

Keterampilan proses sains (KPS) siswa dalam pembelajaran fisika masih perlu diperkuat, terutama pada materi yang menuntut kegiatan eksperimen seperti kalor. Penelitian ini bertujuan mendeskripsikan perkembangan KPS siswa setelah penerapan pembelajaran inkuiri berbantuan scaffolding teknik *cueing* serta mengidentifikasi faktor yang menjadi penyebab peningkatan KPS siswa setelah pembelajaran. Penelitian berupa studi deskriptif kuantitatif pada satu kelompok tanpa kelas pembanding, dengan subjek 22 siswa Fase F MAN 4 Batang Hari yang mengikuti tiga pertemuan. Data dikumpulkan melalui lembar observasi KPS (mengamati, mengukur, mengklasifikasikan, dan menyimpulkan) serta lembar observasi keterlaksanaan pembelajaran yang memuat aktivitas guru dan siswa, kemudian dianalisis secara deskriptif pada setiap pertemuan. Dari pertemuan pertama ke ketiga, persentase indikator mengamati naik dari 48,8% menjadi 82,9%, indikator mengukur dari 51,1% menjadi 79,5%, indikator mengklasifikasikan dari 56,8% menjadi 86,3%, dan indikator menyimpulkan dari 64,7% menjadi 85,2%. Skor aktivitas guru naik dari 2,43 menjadi 3,85 dan aktivitas siswa dari 2,14 menjadi 3,71. Berdasarkan hasil pengamatan observer menunjukkan bahwa pada awal pembelajaran siswa masih sering memerlukan arahan guru, sedangkan pada pertemuan berikutnya arahan yang dibutuhkan makin sedikit seiring meningkatnya keterlibatan siswa. Faktor yang diduga mempengaruhi perkembangan KPS adalah bimbingan guru yang makin berkurang sesuai kebutuhan siswa, pengalaman eksperimen yang berulang, dan meningkatnya keakraban siswa dengan tahapan inkuiri.

Kata Kunci:
Keterampilan Proses Sains, Cueing, Scaffolding, Pembelajaran Inkuiri, Materi Kalor.

Abstract

Students' science process skills (SPS) in physics instruction require further strengthening, particularly in topics that necessitate experimental activities, such as heat. This study aims to describe the development of students' SPS following the implementation of inquiry-based learning supported by "cueing" scaffolding, and to identify the factors contributing to the improvement of these skills. The research employed a quantitative descriptive design with a single group (no comparison class), involving 22 students in Phase F at MAN 4 Batang Hari over the course of three sessions. Data were collected using an SPS observation sheet (covering the skills of observing, measuring, classifying, and drawing conclusions) and an instructional implementation observation sheet (tracking teacher and student activities), which were then analyzed descriptively for each session. From the first to the third session, the percentage of students demonstrating the "observing" indicator rose from 48.8% to 82.9%; "measuring" increased from 51.1% to 79.5%; "classifying" grew from 56.8% to 86.3%; and "drawing conclusions" improved from 64.7% to 85.2%. Scores for teacher activity increased from 2.43 to 3.85, while student activity scores rose from 2.14 to 3.71. Observations indicated that, early in the instruction, students frequently required teacher guidance; however, as their engagement increased, the need for such guidance diminished. Factors believed to have influenced the development of SPS include the tapering of teacher guidance in response to student needs, repeated experimental experience, and the students' growing familiarity with the stages of inquiry.

Keyword:
Science Process Skills, Cueing, Scaffolding, Inquiry-Based Learning, Heat-Related Subject.

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INTRODUCTION

Science process skills (SPS) enable students to engage as active participants in scientific endeavors, rather than merely as passive recipients of pre-existing knowledge. Through activities such as observing, measuring, organizing data, identifying patterns, and drawing conclusions, students connect phenomena with physics concepts. Consequently, the quality of physics instruction should be evaluated not only by students'

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ability to answer conceptual questions but also by their capacity to employ scientific procedures to obtain and interpret evidence (Darmaji et al., 2022).

The topic of heat offers numerous opportunities to cultivate SPS, as concepts such as temperature, heat transfer, and phase changes can be explored through observable phenomena investigated via experiments and data derived from measurements. According to Gunawan et al. (2019), the implementation of guided inquiry through virtual laboratories can enhance students' SPS regarding the concept of heat. Nevertheless, practical laboratory activities do not automatically foster SPS. In another study, Tanti et al. (2020) identified challenges related to students' SPS during laboratory work on temperature and heat. A similar situation was observed during preliminary observations at MAN 4 Batang Hari in October 2025: the mastery rate for the topic of heat in class F.1.1 was only 54% (12 out of 22 students), with students tending to be passive as instruction consisted primarily of the teacher delivering information. While this figure does not serve as a direct measure of SPS, it provides a rationale for examining SPS within an instructional framework that offers students firsthand investigative experience.

Inquiry-based learning provides a structure for students to construct knowledge through questioning, evidence, reasoning, and the evaluation of outcomes. A synthesis by Minner et al. (2010) links inquiry-based learning to student engagement in scientific thinking, while a meta-analysis by Furtak et al. (2012) indicates that the impact of inquiry-based learning varies depending on the level of teacher guidance provided. Aktamış et al. (2016) reported, through a meta-analysis, a positive trend regarding the impact of inquiry-based learning on science process skills (SPS). More recent research highlights the potential of guided inquiry particularly when integrated with laboratory tools or technology (Amrullah et al., 2025; Fitriyana et al., 2025; Rahman et al., 2025). The outcomes of inquiry appear to be determined not solely by student activity, but also by the nature of the support provided by the teacher.

Students with limited experience in scientific investigation may understand the purpose of an experiment, yet struggle to determine what to observe, how to take measurements, how to organize their findings, and which evidence is relevant for drawing conclusions. Temporary support designed to bridge the gap between a student's current ability and the demands of a task is known as "scaffolding" (Belland, 2017). Ideally, such support should be contingent adjusted based on the student's needs gradually faded, and aimed at shifting responsibility toward the student (Van de Pol et al., 2010). One form of this is "cueing," which involves providing hints, guiding questions, or signals that direct a student's attention to critical aspects of a task without explicitly revealing the answer. Petersen (2022) suggests that teachers employ different scaffolding strategies depending on a student's level of understanding regarding inquiry, while Sasse et al. (2025) examine both planned teacher guidance and spontaneous scaffolding within inquiry-based activities among elementary school students. Furthermore, Strata et al. (2024) demonstrate that inquiry-based science education manifests in various forms and degrees of openness. These findings imply that, beyond the mere presence or absence of cueing, it is essential to consider how the support itself evolves throughout the learning process.

In addition to teacher support, the development of science process skills (SPS) can also be influenced by students' experiences in laboratory activities. Nurdiansah et al. (2024) identify laboratory-based instruction as a context that fosters the development of SPS. Through laboratory activities, students have the opportunity to develop SPS in an integrated and continuous manner ranging from observing phenomena, taking measurements to obtain data, and classifying and comparing data, to using empirical evidence as a basis for drawing conclusions. Thus, direct experience in laboratory activities allows students to practice and develop their SPS through the process of scientific inquiry. Most previous studies have focused on changes in scores as the primary outcome. To date, there is limited information regarding how teacher assistance evolves from one session to the next, and how such changes correspond to the development of student behavior particularly concerning the topic of heat within the context of Islamic senior high school education.

This study aims to describe the development of four SPS indicators (observing, measuring, classifying, and drawing conclusions) following the implementation of inquiry-based instruction supported by "cueing" scaffolding techniques focused on the topic of heat over three sessions and to identify the factors potentially underlying this development, based on observations of how teacher and student activities were carried out. As this study does not employ a comparison group, the findings should be interpreted as an overview of development within a single group, rather than as a test of the causal effects of the cueing technique.

METHODS

Research Design

This research is a quantitative descriptive study using a single-group design without a comparison group. The development of science process skills (SPS) and the implementation of instruction were observed

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repeatedly across three sessions. This design was chosen because the research objective is to describe changes in achievement from one session to the next, along with the accompanying instructional conditions, rather than to compare two different treatments. The quantitative descriptive research design is illustrated in Table 1 below:

Tabel 1. Research Design

Session	Treatment	Observation (Obs SPS + Obs teacher student)
Session 1	Inquiry + *Scaffolding Cueing* (X_1)	$Obs_1^K + Obs_1^{GS}$
Session 2	Inquiry + *Scaffolding Cueing* (X_2)	$Obs_2^K + Obs_2^{GS}$
Session 3	Inquiry + *Scaffolding Cueing* (X_3)	$Obs_3^K + Obs_3^{GS}$

Note:
X_1, X_2, X_3 : Treatment for each session
Obs_1^k, Obs_2^k, Obs_3^k : KPS (Science Process Skills) observation
Obs_1^{KG}, Obs_2^{KG}, Obs_3^{KG} : Teacher and student observation
The study involves a single class, with no comparison class.

Research Subjects and Learning Context

The study was conducted at MAN 4 Batang Hari with 22 students in Phase F, this was because MAN 4 Batang Hari has only one class studying physics. The subject matter covered was heat, spanning three sessions: the first session focused on the concept of temperature, the second on the concept of heat, and the third on heat transfer. The instruction followed an inquiry-based framework consisting of the following stages: orientation, problem formulation, hypothesis formulation, data collection, data analysis, drawing conclusions, and evaluation and reflection.

"Cueing" was provided whenever students encountered difficulties during the inquiry process. This took the form of hints, guiding questions, or prompts designed to focus students' attention on relevant information, the examination of procedures, or the review of data. The teacher did not provide the final answers directly; instead, the intensity of the support was adjusted based on the students' observed needs during the activities, ensuring that the students remained responsible for their own inquiry.

Instruments and Data Collection

Data were collected using two types of observation sheets: a Science Process Skills (SPS) observation sheet and an instructional implementation observation sheet, which covers both teacher and student activities. The SPS observation sheet includes four SPS indicators. Observing involves the ability to recognize phenomena and record relevant information. Measuring entails the use of measuring instruments, reading results, and recording data. Classifying involves grouping or comparing data based on specific characteristics. Drawing conclusions involves using evidence to formulate explanations or inferences.

Table 2. Blueprint for the SPS observation sheet

No	Indicator SPS	Success Indicator	Rating Scale	Number of Items
1	Observing	Accuracy and completeness of information obtained through observation	1-4	1
2	Measuring	Appropriateness of instrument selection, scale reading, execution of measurements, and data recording	1-4	1
3	Classifying	Appropriateness of criteria and suitability of the grouping of experimental data	1-4	1
4	Concluding	Accuracy of conclusions based on the data and their connection to concepts of temperature and heat.	1-4	1
	Total	Four SPS aspects		4

The implementation observation sheet consists of seven inquiry stages, with each stage containing specific indicators for both teacher and student activities. Teacher indicators include providing stimuli, guiding the formulation of problems and hypotheses, facilitating experiments, assisting with data analysis and the drawing of conclusions, and providing opportunities for reflection. Student indicators include engaging in the observation of phenomena, discussing problems, proposing hypotheses, conducting experiments and participating within groups, analyzing data, formulating conclusions, and reflecting. Each stage is assigned a score from 1 to 4 for both the teacher and the students, with an accompanying section for observer comments. The teacher's score is determined by the extent to which the indicators are met, while the student's score is

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based on their level of active participation and the independence of their scientific thinking. Observations are conducted by a single observer during each session specifically, the physics teacher at MAN 4 Batang Hari.

Table 3. Grid for the observation sheet on the implementation of learning (teacher and student activities)

No	Aspect Observed	Indicator Key	Activities Assessed	Number of Item
1	Teacher Activity	Implementation of inquiry stages	Presentation of phenomena, guidance in formulating problems and hypotheses, guidance during experiments, data analysis, drawing conclusions, and reflection	7 items
2	Student Activity	Participation in the inquiry process	Response to phenomena, formulation of problems and hypotheses, conducting experiments, data analysis, drawing conclusions, and reflection	7 items
Total			7 stages observed for both teacher and student activities	14 assessments

Data Analysis

Science process skills (SPS) data were analyzed descriptively by calculating the percentage of achievement for each indicator across every session. Changes were determined by calculating the difference in percentages between the first and third sessions, expressed in percentage points. Throughout the research process, an observer conducted evaluations to assess the implementation of the students' science process skills indicators. The maximum possible score was calculated by multiplying the 4 SPS indicators by the total number of students (22). The data were examined using the following formula:

$$\text{Indicator Percentage} = \frac{the\ total\ score\ obtained}{maximum\ score} \times 100$$

Table 4 Criteria for the implementation level of science process skill (SPS) indicators

Percentage value	Category
86-100	Very good
76-85	Good
55-75	Fair
≤54	Poor

(Arikunto, 2014)

Furthermore, the observer also conducted observations to evaluate the implementation of the learning model, including the activities of both the teacher and the students. The data were analyzed using the following formula:

$$\text{Average} = \frac{\boldsymbol{the\ total\ score\ obtained}}{\boldsymbol{number\ of\ inquiry\ syntax\ indicators}}$$

Table 5 Criteria for the implementation level of the inquiry syntax

Average Earnings Value	Category
3,25-4,00	Very Active
2,50-3,24	Active
1,75-2,49	Moderately Active
≤1,75	Less Active

RESULTS AND DISCUSSION

Development of Science Process Skill (SPS) Indicators

All four SPS indicators showed an increase from the first to the third session (Table 1). The largest increase occurred in "observing" (34.1 percentage points), while the smallest increase was in "concluding" (20.5 percentage points). By the third session, all indicators were above 79%, with "classifying" being the highest (86.3%) and "measuring" being the lowest (79.5%).

Table 6. Percentage of achievement for SPS indicators across three sessions

Indicator	Session 1	Session 2	Session 3	Δ (poin persentase)
Observing	48,8%	70,4%	82,9%	34,1
Measuring	51,1%	64,7%	79,5%	28,4
Classifying	56,8%	75,0%	86,3%	29,5
Concluding	64,7%	79,5%	85,2%	20,5

For the "observing" indicator, the achievement level rose from 48.8% to 82.9%. In the first session, students still required guidance to distinguish between important information and less relevant details, whereas in subsequent sessions, their observations became more structured. The "measuring" indicator increased by 28.4 percentage points, from 51.1% to 79.5%. This shift reflects a transition from using measuring tools that

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required constant supervision toward more consistent measurement and recording a crucial aspect when studying heat, as temperature data serves as the foundation for comparing conditions and formulating explanations.

The "classifying" indicator rose by 29.5 percentage points, reaching 86.3%, which indicates that students became increasingly adept at identifying patterns, similarities, and differences within their observations. The "concluding" indicator increased by 20.5 percentage points, from 64.7% to 85.2%. While this represents the smallest gain, it started from the highest baseline among the four indicators. Progress in this area was particularly evident in the students' ability to link their conclusions to the evidence gathered, rather than simply producing a final statement.

Teacher and Student Activities

The teacher activity score increased from 2.43 in the first session to 3.14 in the second session, and to 3.85 in the third session. The student activity score rose from 2.14 to 3.00, and subsequently to 3.71 (Table 7). Based on the criteria provided in the observation sheet, both components fell into the "moderately active" category during the first session, "active" during the second session, and "very active" during the third session.

Table 7. Average scores for teacher and student activities across three sessions (scale 1–4)

Component	Session 1	Session 2	Session 3	Change
Teacher Activity	2,43	3,14	3,85	+1,42
Student Activity	2,14	3,00	3,71	+1,57

The details for each stage of the inquiry process are presented in the table below. In the first session, the lowest score (2) was recorded for problem formulation, hypothesis formulation, data analysis, and drawing conclusions for both the teacher and the students while data collection received a score of 3. The observer noted that the the guiding questions failed to engage all students; the hypotheses proposed were too general and lacked a foundation in physics concepts; group participation was uneven, requiring frequent intervention and direction from the teacher; and several groups needed guidance in formulating problems and drawing conclusions.

Table 8. Teacher/student activity scores per inquiry stage (scale 1–4)

Stages Inquiry	Session 1	Session 2	Session 3	Difference (S3–S1)
Orientation	3 / 2	3 / 3	4 / 4	+1 / +2
Formulation of the problem	2 / 2	3 / 3	4 / 4	+2 / +2
Formulation of the hypothesis	2 / 2	3 / 3	3 / 3	+1 / +1
Data collection	3 / 3	4 / 3	4 / 3	+1 / 0
Data analysis	2 / 2	3 / 3	4 / 4	+2 / +2
Drawing conclusions	2 / 2	3 / 3	4 / 4	+2 / +2
Evaluation and reflection	3 / 2	3 / 3	4 / 4	+1 / +2

In the second session, nearly all stages received a score of 3 for both the teacher and the students, with the teacher's data collection process reaching a score of 4. The observer noted that most groups were already capable of formulating problems and interpreting data, requiring only minimal guidance. In the third session, the teacher achieved a score of 4 in six stages, while the students reached this score in five stages. A score of 3 remained only for the formulation of hypotheses (for both the teacher and students) and data collection (for the students). During this session, the observer noted that all groups formulated relevant problems, group members participated actively, and the students constructed conclusions using precise physics terminology.

Discussion

Cueing as Support Tailored to Student Needs

Findings in Tables 7 and 8, along with observer notes, provide insight into how cueing functioned during instruction. In the first session, students were not yet accustomed to the demands of inquiry; the teacher frequently provided direction to several groups, and many students required guidance in formulating problems, developing hypotheses, connecting data to concepts, and drawing conclusions. By the second session, only a small number of groups still required direction, and the level of guidance needed was minimal. In the third session, the observer noted that the teacher's guidance was well-timed, and discussions were active. As the notes do not specify the exact form of each cue (e.g., a hint, a guiding question, or a signal), it cannot be definitively concluded that the cues became increasingly specific.

This aligns with the perspective that scaffolding is effective when it is contingent, gradually faded, and shifts responsibility toward the students (Van de Pol et al., 2010). Petersen (2022) reported that teachers employ

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different scaffolding strategies based on students' levels of understanding regarding inquiry. In a study involving elementary school students, Sasse et al. (2025) found that a teacher's spontaneous scaffolding is linked to a planned sequence of guidance, while Furtak et al. (2012) observed that the impact of inquiry varies depending on the level of teacher guidance provided. In this study, the value of cueing lies in the alignment between the support offered and the students' needs at any given moment. Excessive cueing may shift the responsibility for the investigation onto the teacher, whereas cues that are too vague may fail to help students overcome obstacles.

Experimental Experience and the Interconnection of Science Process Skills (SPS) Indicators

Improvements in the "observing" and "measuring" indicators suggest that experimental activities serve as a space for procedural practice. Students do not merely learn how to measure a quantity; they actively perform measurements and engage with the implications of the data they obtain. This is significant because science process skills (SPS) have a performative dimension: an individual may understand a procedure declaratively without necessarily being able to apply it accurately. These findings align with those of Nurdiansah et al. (2024) and Gunawan et al. (2019), who identify laboratory experience as the context for the development of SPS, including in the study of heat-related concepts. "Measuring" emerged as the indicator with the lowest achievement in the third session (79.5%), suggesting that the precise use of equipment and accurate data recording may require more extensive practice than what was provided over the three sessions.

The four indicators are also interdependent. Observation yields initial information, measurement transforms this into data, classification helps students identify patterns within that data, and drawing conclusions utilizes these patterns as evidence. A simultaneous increase across all four indicators suggests that students had the opportunity to engage in the entire sequence of these processes. The most substantial improvement in "observing" can be interpreted as an indication that the initial stage of inquiry is becoming internalized, while the more modest gain in "drawing conclusions" should be viewed in the context of its higher starting point. Tiaradipa et al. (2020) developed scaffolding within an inquiry-based learning framework to enhance SPS in the context of acid-base topics, while Nengsih et al. (2023) reported on the impact of "Predict-Observe-Explain" (POE)-oriented worksheets on SPS. Agustiani et al. (2022) analyzed SPS using PISA-based tests and observational instruments; the latter is particularly relevant to this study, as these skills are manifested through the actions students take while conducting an investigation.

Familiarity with Inquiry Stages and Student Engagement

Student activity increased from 2.14 to 3.71, indicating that student engagement was not static across the three sessions. One possible explanation is that students became increasingly familiar with the structure of the activities. In the first session, a portion of the students' attention was likely directed toward understanding what they were required to do; in subsequent sessions, that attention could be focused on the content of the inquiry. Repeating the learning structure can thus help establish scientific routines. Dah et al. (2024) note that the level of inquiry openness influences students' learning experiences. For students not yet prepared to engage in inquiry independently, "cueing" provides a structure that keeps the activities moving, while repeated experience helps them recognize the flow of the inquiry process.

The concurrent increase in both teacher and student activity must be interpreted with caution. A higher score for teacher activity does not necessarily imply that the teacher has become more dominant; in inquiry-based learning, such a score may reflect more effective management of the learning environment, monitoring, the use of guiding questions, and the provision of feedback. Meanwhile, a higher score for student activity reflects more active participation in observation, experimentation, discussion, and decision-making. The observation instrument was not designed to test the direction of relationships between variables; therefore, these increases cannot be used to infer correlation or causality. It can only be stated that the interaction between teacher and student appears to have become more structured: the teacher provides more scaffolding at the beginning of the learning process, while students subsequently take on a larger share of the activity with progressively less direct guidance. The reduction of support should be aligned with student readiness for instance, when issues such as measurement errors, incomplete data recording, or conclusions unsupported by evidence no longer occur rather than being determined solely by the progression to the next lesson session.

The breakdown by stage in Table 8 provides further insight. In the first session, the stage requiring students to formulate ideas (identifying problems, hypotheses, analyses, and conclusions) received the lowest score, whereas procedural experimental activities scored 3. By the third session, the formulation of hypotheses remained one of the lower-scoring stages. Observers noted that, in the first session, students' hypotheses were too general and lacked a foundation in physics concepts. This suggests that connecting conjectures to scientific concepts requires more time and may necessitate more targeted "cueing" (guidance/prompts). Since the

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Science Process Skills (SPS) indicators being monitored did not explicitly include hypothesis formulation, these conjectures could not be directly linked to the SPS data.

Positioning of Findings Relative to Previous Research and Their Implications

These findings align with research indicating that inquiry-based learning supports the development of Science Process Skills (SPS) (Suryawanto et al., 2022; Zahra et al., 2023). Rato et al. (2024) reported an improvement in SPS through virtual laboratory-based inquiry learning using a pretest–posttest design; Rahman et al. (2025) found that guided inquiry utilizing laboratory media fosters both SPS and problem-solving abilities; and Fitriyana et al. (2025) observed improvements in both SPS and physics learning outcomes through guided inquiry. While such studies generally focus on the score differential between two points in time, the present study provides a more detailed picture of how indicator achievement evolves across sessions alongside corresponding shifts in teacher and student activities thereby offering insight into the processes occurring between those two measurement points.

These findings carry several implications for educators. "Cueing" should focus on the scientific process such as variables, data, procedures, or the relationships between pieces of evidence rather than on the final answers, ensuring that students retain ownership of their scientific decision-making. The need for such cues can be determined through formative observation of student errors or points of confusion. Inquiry needs to be conducted repeatedly so that students become accustomed to the process, and the assessment of science process skills (SPS) should combine tests with observations of the process itself.

Research Limitations

This research has several limitations. First, the subjects were only 22 students from one school so the findings mainly describe the class studied. Second, without a comparison class, the increase in KPS cannot be attributed solely to cueing; experimental experiences, inquiry learning itself, repetition of tasks, and student development can contribute. Therefore, the factors discussed above are conjectures derived from observational patterns and literature, not test results. Third, the activity data is descriptive in nature so that the frequency of each type of cueing, the duration of assistance, student responses after cueing, and the sequence of interactions have not been analyzed. The activity assessment was also carried out by one observer so inter-observer reliability cannot yet be demonstrated. Fourth, learning only lasted three meetings so the sustainability of the improvement is not yet known.

CONCLUSION

Over the course of three inquiry-based learning sessions on the topic of heat supported by "cueing" as a scaffolding technique students' science process skills (SPS) improved across all four measured indicators: observing (by 34.1 percentage points), measuring (28.4 percentage points), classifying (29.5 percentage points), and drawing conclusions (20.5 percentage points). During the same period, scores for teacher activity increased from 2.43 to 3.85, while student activity scores rose from 2.14 to 3.71.

Factors likely contributing to this progress include the use of cueing tailored to individual student needs, repeated experimental experience, and students' growing familiarity with the stages of inquiry. As this study lacked a comparison group and the data were analyzed using descriptive quantitative methods, the relationship between cueing and SPS cannot be definitively characterized as causal.

Future research should employ a comparative design, cover a longer instructional period, and incorporate a micro-analysis of the types, frequency, and timing of cues, as well as student responses to them.

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