

A Systematic Literature Review of Science Process Skills in Indonesia: Insights on Research Designs, Data Analysis Methods, and Implications for Future Research

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Abstract— Research on science process skills (SPS) in Indonesia has grown rapidly over the past decade; however, no comprehensive synthesis has yet been conducted on the research designs and data analysis techniques employed in these studies. This study aims to identify, evaluate, and synthesize SPS research in Indonesia from 2015 to 2025, with a specific focus on research designs and data analysis methods. The review followed the PRISMA 2020 guidelines. Literature searches were conducted in SciSpace (1,085 articles), Google Scholar (58 articles), and PubMed (0 articles) using keywords related to science process skills and Indonesia. After removing duplicates, 87 unique articles were screened based on title and abstract, yielding 20 articles for full-text assessment, of which 19 met the inclusion criteria and were analyzed in depth. Among these 19 studies, quasi-experimental designs predominated ($n = 14$; 73.7%), followed by pre-experimental designs ($n = 3$; 15.8%) and other designs, including development and descriptive studies ($n = 2$; 10.5%). The most frequently used data analysis methods were t -tests ($n = 11$; 57.9%), N -Gain ($n = 8$; 42.1%), and ANCOVA ($n = 2$; 10.5%). Most studies were conducted at the senior secondary ($n = 9$; 47.4%) and higher education levels ($n = 3$; 15.8%). Guided inquiry learning emerged as the most commonly investigated intervention, consistently yielding significant gains in students' SPS. Overall, SPS research in Indonesia remains dominated by quasi-experimental, quantitatively oriented designs, indicating the need for greater diversification, including longitudinal, mixed-methods, and qualitative studies, along with standardization of SPS measurement instruments, improved methodological reporting, and exploration of more diverse learning contexts. Despite the rapid growth of SPS research in Indonesia, diversity in research designs and data analysis methods complicates synthesis and limits comparability. This review emphasizes methodological patterns, identifies research gaps, and provides recommendations for future studies and educational practice

Keywords— Science Process Skills, Systematic Review, Research Design, Data Analysis Methods, Indonesia, PRISMA.

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1. Introduction

Science process skills (SPS) are considered a key competency in science education because they provide the foundation for students to conduct scientific investigations systematically, critically, and evidence-based [1]. SPS encompasses a set of intellectual, social, and psychomotor skills that enable students to engage in the scientific process, from observing, classifying, measuring, and inferring, to formulating hypotheses, identifying variables, designing and conducting experiments, interpreting data, and communicating findings [2]. Mastery of these skills is not only essential for understanding science content but also for developing critical thinking, problem-solving, and lifelong learning skills that are essential in a 21st-century knowledge-based society [3]. Within the framework of modern curricula, including the science education curriculum in Indonesia, SPS is positioned as an integral part of core competencies and basic competencies that must be developed through classroom learning and practical activities. The curriculum demands that science learning not only stops at mastering concepts but also fosters an understanding of how scientific knowledge is generated through the process of inquiry [4]. However, the implementation of learning that consistently

develops SPS still faces various challenges, such as limited laboratory facilities, a lack of teacher training in inquiry-based pedagogy, and a learning culture that is still dominated by conventional teacher-centered methods [5].

In response to these challenges, various innovative learning models and approaches have been developed and researched in the Indonesian context, including inquiry-based learning [6], contextual learning [7], problem-based learning, the POGIL (Process Oriented Guided Inquiry Learning) model [8], the CLIS (Children's Learning in Science) model [9], STEAM-based learning [10], blended learning [11], and technology integration in the form of interactive e-modules and virtual labs [12], [13]. These interventions are designed to provide more active and meaningful learning experiences, by positioning students as the main actors in scientific investigations, not simply recipients of information. Over the past decade, research on SPS in Indonesia has grown rapidly, resulting in numerous empirical studies evaluating the effectiveness of various learning interventions at various levels of education, from elementary school to university. These studies utilize diverse contexts, such as regular classroom learning, laboratory practicums, virtual practicums, project-based learning, and learning that integrates local wisdom. In general, reported findings indicate that inquiry-based interventions and other active approaches tend to contribute positively to improving SPS, although the degree of effectiveness and the skills developed are not always consistent across studies

However, despite the abundance of publications on SPS, significant issues remain regarding the heterogeneity of research designs, measurement instruments, and data analysis methods used. Most studies employ quantitative approaches with quasi-experimental designs, primarily pretest-posttest designs with non-randomized control groups, while others employ pre-experimental, descriptive, research and development, or mixed-methods designs. On the one hand, this diversity reflects the dynamism and creativity of researchers; on the other hand, it makes it difficult to directly compare results across studies or to synthesize robust evidence at a methodological level. Similar issues arise in the realm of data measurement and analysis. The SPS instruments used in various studies differ in terms of indicators, test formats (objective, descriptive, or performance), and scoring procedures. Many studies measure SPS broadly as a single construct, while others measure basic and integrated skills separately, such as observing, measuring, classifying, inferring, formulating hypotheses, identifying variables, designing experiments, and analyzing data. Furthermore, the variety of analytical techniques, such as the use of t-tests, ANCOVA, non-parametric tests, N-Gain calculations, effect sizes, and qualitative thematic analysis, creates a rich but challenging methodological landscape.

In this context, systematic literature reviews are crucial for comprehensively mapping how research on SPS in Indonesia is designed and analyzed. Unlike traditional narrative reviews, systematic reviews follow explicit and transparent procedures for searching, selecting, and synthesizing studies, thereby minimizing selection bias and increasing the reproducibility of findings. The use of the PRISMA 2020 guidelines in designing and reporting systematic reviews also ensures that each stage, from article identification, screening, and eligibility determination to study inclusion in the synthesis, is well documented [14]. While these findings paint an optimistic picture for SPS development efforts in Indonesia, the review also identified a number of methodological limitations that recur across many studies. These include small sample sizes, underreporting of sampling methods, limited information on the validity and reliability of SPS instruments, the absence of reporting statistical assumption tests when using parametric tests, and the infrequent reporting of effect sizes. Furthermore, almost all studies were cross-sectional or short-term interventions without follow-up measurements, making it difficult to assess the durability or retention of the skills developed.

Based on this background and initial findings, this systematic literature review was prepared with the primary objective of identifying, evaluating, and synthesizing empirical evidence on science process skills in Indonesia for the period 2015–2025 from the perspective of research design and data analysis methods used. Specifically, this review seeks to answer questions about: (1) the types and characteristics of research designs most frequently used in SPS studies in Indonesia; (2) the dominant data analysis methods and how they were applied; (3) the distribution of studies by educational level, geographic location, and sample size; (4) the specific science process skills measured and the instruments used; and (5) the most widely researched learning models and interventions to improve SPS. By providing a structured mapping of these aspects, this study is expected to offer a strong empirical foundation for the development of future SPS research. From a theoretical perspective, this review contributes to an understanding of how SPS is conceptualized and operationalized in the context of Indonesian science education. From a methodological perspective, the results of the synthesis are expected to encourage improvements in research design, reporting quality, and standardization of SPS measurement. Meanwhile, from a practical perspective, information on effective learning models, under-explored educational levels, and diverse implementation contexts can serve as a reference for educators, curriculum developers, and policymakers in designing more targeted and evidence-based interventions. Finally, by focusing on research conducted in Indonesia, this review also seeks to showcase the contributions of the national science education community to the global discourse on science process skills. A comprehensive overview of the SPS research landscape in Indonesia is not only relevant for internal improvements to the national education system but also has the potential to serve as a reference for other countries facing similar challenges in integrating SPS into science learning at various levels of education. While prior studies focused mainly on the effectiveness of learning interventions, few have systematically examined methodological characteristics of SPS research in Indonesia. This review addresses this gap, providing insights on study design, data analysis, and measurement practices, and aims to inform both researchers and educators.

2. Method

This systematic review follows the PRISMA guidelines, with transparent documentation of methodological procedures, although the protocol was not registered prospectively. The study selection criteria were based on the PICOS framework, articles were included if they (1) focused on SPS in the Indonesian context, (2) reported empirical results, (3) provided clear research design and data analysis methods, and (4) were published between 2015 and 2025 in English or Indonesian. Excluded were non-empirical studies, studies without methodological clarity, or those not focusing on SPS. Literature searches were conducted in SciSpace (1,085

articles), Google Scholar (58 articles), and PubMed (0 articles), resulting in 87 unique articles after deduplication. The selection process proceeded in stages title and abstract screening (87 articles), full-text screening (20 articles), and finally, 19 articles that met the inclusion criteria were retained for analysis. Data were systematically extracted to include study characteristics, research design, interventions, data analysis methods, and main findings. Methodological quality of included studies was assessed descriptively based on sample size, clarity of data collection and analysis, and instrument reporting. Data synthesis was performed narratively and in tabular form due to study heterogeneity, focusing on research design, data analysis methods, study distribution, measured skills, as well as the learning models and interventions investigated. The PRISMA guidelines and the stages of identification, screening, eligibility, and inclusion are illustrated in Figure 1.

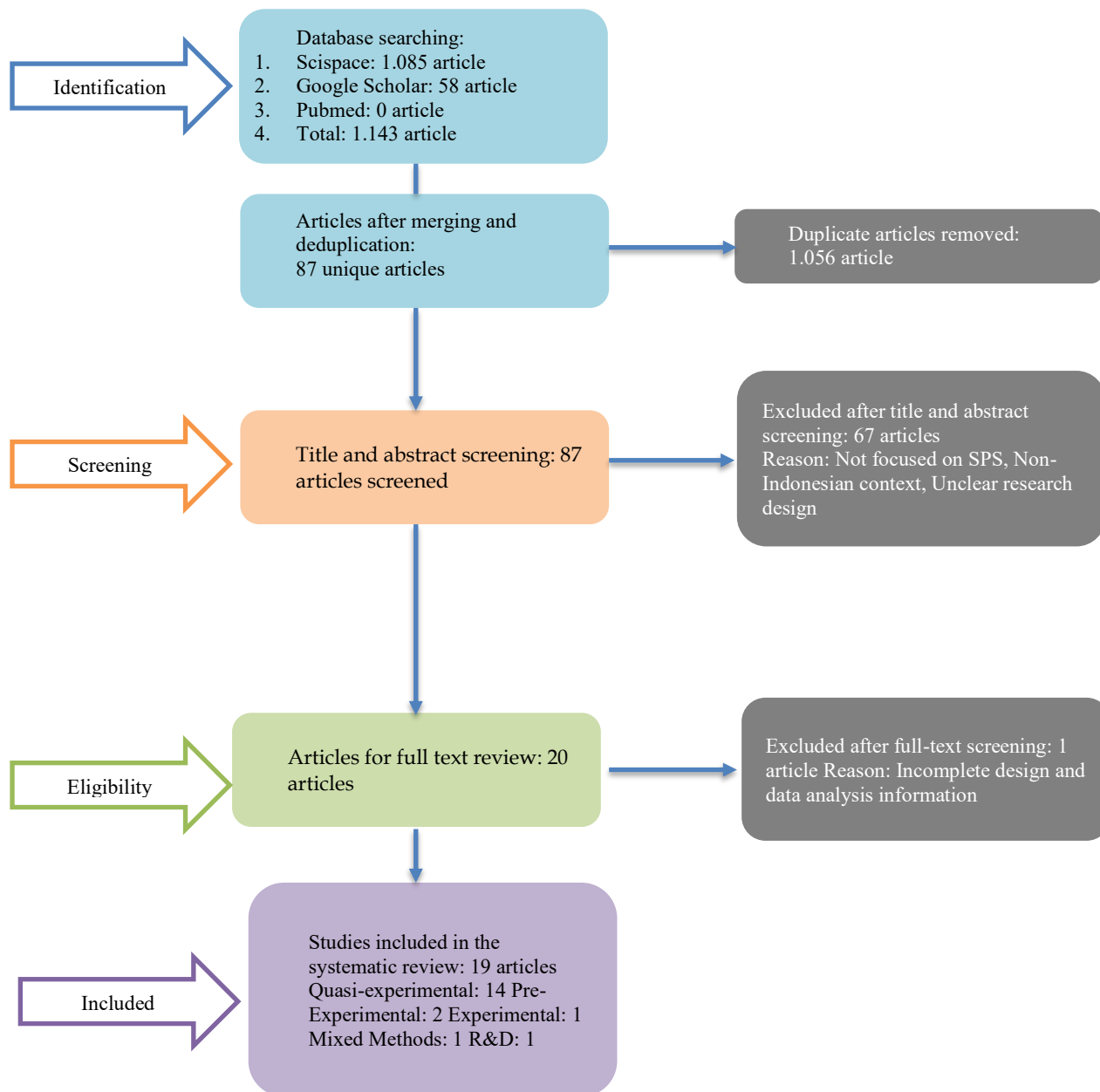


Figure 1. PRISMA guidelines and results of identification, screening, eligibility, and inclusion.

3. Result and Discussion

A. Result

1) Study Selection

The literature screening process was systematically conducted following the PRISMA approach, beginning with 1,143 identified articles and refined to 87 unique records after removing duplicates. Based on title and abstract screening, 20 articles proceeded to the full-text review stage, with one article subsequently excluded due to unclear methodology. Consequently, 19 valid and unique studies were included in the final synthesis. This outcome demonstrates that the selection process was rigorous and focused on scientific quality and relevance, ensuring the authenticity and credibility of the sources used in the research. Moreover, the proportion of articles that passed the screening reflects the effectiveness of the applied inclusion criteria, highlighting that this review

relies solely on literature with robust methodologies and reliable data to produce a meaningful synthesis that supports the validity of the final findings.

2) Study Characteristics

Table 1 presents the complete characteristics of the 19 studies included in this systematic review, encompassing information on the authors, year of publication, study location, educational level, sample size, research design, data analysis methods, measured science process skills, and main findings. The synthesis revealed a clear dominance of quasi-experimental designs (14 out of 19 studies), primarily pretest-posttest non-equivalent control group designs, highlighting a methodological focus on practical classroom interventions but limited internal validity.

Table 1. Characteristics of Included Studies

No	Authors & Year	Location	Educational Level	Sample Size	Research Design	Data Analysis Methods	Science Process Skills (SPS) Measured	Main Findings
1	Artayasa et al. (n.d.) [15]	University of Mataram, Mataram	Higher education (primary teacher education)	154	Quasi-experimental pretest–posttest non-equivalent control group	ANCOVA, Kruskal–Wallis	Integrated SPS: designing procedures, collecting data, presenting data, discussing data, drawing conclusions	Three levels of inquiry differed significantly from conventional strategies; open inquiry was most effective for integrated SPS [15]
2	Ningsih (2017) [7]	SMA Unggul N 4 Palembang, Palembang	Upper secondary (Grade XI)	Not reported	Quasi-experimental matching-only pretest–posttest control group	Independent t-test	General SPS	Inquiry-based CTL produced higher post-test SPS (84.26 vs 70.85), difference statistically significant [7]
3	Hardianti & Kuswanto (2017) [16]	Not reported	Upper secondary	Not reported	Quasi-experimental pretest–posttest non-equivalent control group with cluster sampling	Gain-score comparison and inferential tests	General SPS	Inquiry level 3 (ILL-3) more effective than ILL-2 and ILL-4 in improving SPS based on gain scores [16]
4	Pramitasa et al. (2025) [10]	Not reported	Not reported	Not reported	Quasi-experimental non-equivalent control group	Percentage analysis, normality & homogeneity tests, independent t-test, effect size calculation	SPS (observation sheets)	STEAM-based inquiry learning significantly improved SPS; effect size = 0.642 (large) [10]
5	Saleh et al. (2024) [17]	SMA Negeri 1 Kodeoha, Southeast Sulawesi	Upper secondary (Grade XI science track)	60 (30 per class)	Quasi-experimental pretest–posttest control group	t-test	SPS (pre/post tests)	Guided inquiry led to a significant increase in SPS ($t = 2.68 > t\text{-table } 2.04$) [17]
6	Haryanto et al. (2019) [6]	University of Jambi, Jambi	Higher education (Physics & Chemistry)	201 (108 Physics, 93 Chemistry)	Quasi-experimental static group comparison	Observation sheets (Likert scale) and comparative statistical tests	Basic SPS: classifying, concluding, measuring; integrated SPS: data processing, relating, graphing, hypothesizing, identifying variables	SPS-based laboratory manual significantly developed SPS; experimental classes outperformed control classes [6]

No	Authors & Year	Location	Educational Level	Sample Size	Research Design	Data Analysis Methods	Science Process Skills (SPS) Measured	Main Findings
7	Sari et al. (2015) [18]	SMA Negeri 1 Unggul Baitussalam	Upper secondary (Grade X)	45	Experimental pretest–posttest control group	SPS test and N-gain for SPS and scientific attitudes; questionnaire for attitudes	SPS and scientific attitudes	Experimental method did not significantly affect SPS or attitudes (N-gain 56%); guided inquiry yielded higher improvements (N-gain 71%) [18]
8	Sumanti et al. (2023) [8]	Not reported	Primary school	58 (29 experimental, 29 control)	Quasi-experimental non-equivalent control group	Inferential statistics using t-test	SPS (essay questions & observation), collaboration skills	POGIL model with animation media significantly improved primary students' SPS and collaboration; SPS indicators were very high [8]
9	Mazidah et al. (2023) [19]	Various locations, Indonesia (review)	Various educational levels	24 articles reviewed	Qualitative review of secondary data	Thematic/content qualitative analysis	SPS and related outcomes (varied)	Guided inquiry-based interactive e-modules showed positive impacts on SPS, critical thinking, scientific literacy, problem-solving [19]
10	Sulistri (2019) [9]	Singkawang	Upper secondary	27	Pre-experimental one-group pretest–posttest	N-gain calculation	Integrated SPS: data interpretation, hypothesis formulation, experimental planning, concept application	CLIS model improved integrated SPS with N-gain = 0.67 (moderate) [9]
11	Tanti et al. (2020) [20]	SMP Adhyaksa 1, Jambi	Lower secondary	Not reported	Mixed-method sequential explanatory	Quantitative observation sheets & qualitative interviews/observations analyzed sequentially	Basic and integrated SPS	Students' SPS on static fluid topics were categorized as good based on observations and interviews [20]
12	Fahmi et al. (2024) [21]	Not reported	Lower secondary (Grade 7)	Not reported	Pretest–posttest control group with combined quantitative & qualitative methods	Quantitative and qualitative analyses of pre/post outcomes	General SPS	Inquiry model produced significant improvements in SPS and learning outcomes compared with control group [21]
13	Maison et al. (2020) [22]	University of Jambi, Jambi	Higher education (science programs)	201	Experimental static group comparison design	SPSS v.24; independent tests with significance $p = 0.000$	SPS mastery	Students using inquiry-based laboratory manuals demonstrated better SPS mastery than those using conventional manuals; differences significant ($p = 0.000$) [22]
14	Bakti et al. (2023) [11]	SMAN 11 Banjarmasin, Banjarmasin	Upper secondary (Grade XI)	Not reported	Quasi-experimental pretest–	Descriptive statistics and t-test	SPS (tests & student responses)	Guided inquiry-based blended learning resulted in higher SPS than

No	Authors & Year	Location	Educational Level	Sample Size	Research Design	Data Analysis Methods	Science Process Skills (SPS) Measured	Main Findings
			science track)		posttest control group with cluster random sampling			guided inquiry alone; student responses were positive [11]
15	Rapsanjani et al. (2025) [23]	SD YPK Tanas	Primary school (Grade 5)	20	Pre-experimental one-group pretest–posttest	N-gain calculation for five SPS indicators	SPS: problem formulation, hypothesis development, variable identification, data analysis, conclusion drawing	Contextual science learning based on local wisdom improved SPS with mean N-gain = 0.82 (high); highest gain in data analysis (0.88) [23]
16	Siti et al. (2019) [24]	Kendal, Semarang, Demak (Central Java)	Prospective lower secondary teachers & students	296 + 4 preservice teachers + 4 mentors	R&D with field testing	Effect size calculation (effect size = 1.5)	Overall SPS with emphasis on observing & measuring; concluding & predicting less optimal	Inquiry-based learning effectively empowered SPS; large effect size (1.5); observing & measuring dominated, concluding & predicting were weaker [24]
17	Halim et al. (2021) [12]	Banda Aceh	Upper secondary	31 per group (EPBL & EBGIL)	Comparative quasi-experimental (two instructional models compared)	N-gain, normality & homogeneity tests, t-test	SPS and conceptual understanding	Significant differences in SPS gain between EBGIL & EPBL groups; EBGIL recommended to enhance SPS & understanding of wave concepts [12]
18	Wiyanto et al. (2022) [13]	SMA Negeri 2 Bandar Lampung, Bandar Lampung	Upper secondary (Grade X science track)	36	One-group pretest–posttest	Normality test, paired-samples test, N-gain analysis	Growth of SPS during virtual practicum on projectile motion	Mean pre/post difference was 7.00 and N-gain = 0.2 (low); Macromedia Flash-based virtual practicum affected SPS growth but with low effect [13]
19	Wulandari & Megawati (2018) [6]	University of Muhammadiyah Sidoarjo, Sidoarjo	Higher education (4th-semester primary education students)	30	Descriptive with pre-experimental design (one-shot case study)	Descriptive statistics: tables, graphs, mean, data dispersion, percentages	SPS: observing, predicting, concluding, communicating	Most students fell into good category for observing, predicting & concluding; communicating reached highest scores [6]

a) Geographic Distribution

The included studies were conducted in various locations across Indonesia, with a concentration on the islands of Sumatra (Palembang, Jambi, Banda Aceh, Bandar Lampung) and Java (Semarang, Kendal, Demak, Sidoarjo). Other studies were carried out in Kalimantan (Banjarmasin, Singkawang) and Sulawesi (Kodeoha). Three studies did not report a specific location, and one study was a literature review covering multiple locations in Indonesia [6].

b) Distribution of Education Levels

The distribution of educational levels was as follows: Senior High School (SMA) accounted for 9 studies (47,4%) [7], [9], [11], [12], [13], [16], [17], [18]; Higher Education for 3 studies (15,8%) [15], [22], [25]; Junior High School (SMP) for 3 studies (15,8%) [20], [21], [24]; Primary School (SD) for 2 studies (10,5%) [8], [23]; not reported for 1 study (5,3%) [4]; and 1 study (5,3%) was a literature review covering multiple educational levels [19]. This distribution is illustrated in Figure 2.

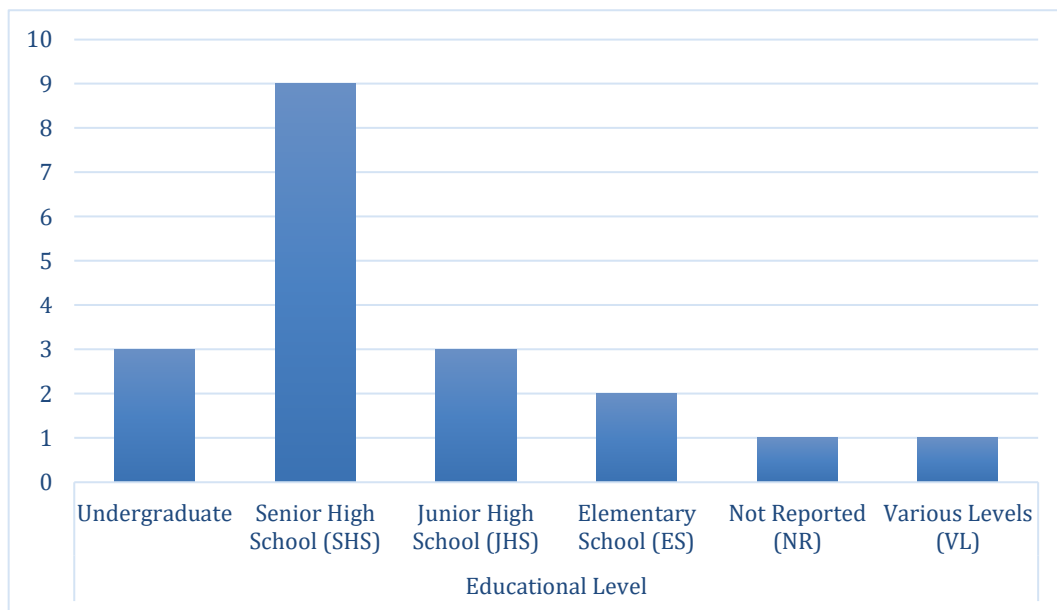


Figure 2. Distribution of educational level

c) Sample Size

The reported sample sizes ranged from 20 to 296 participants. The study with the largest sample was conducted by Siti et al. (2019) with 296 students [24], followed by Haryanto et al. (2019) and Maison et al. (2020), each with 201 participants [22], [25]. Even studies did not explicitly report their sample size in the abstract [7], [10], [11], [16], [20], [21].

3) Research Design Synthesis

The analysis of the 19 included studies revealed a dominance of quasi-experimental designs in research on science process skills in Indonesia. Table 2 presents the distribution of the research designs employed.

Table 2. Distribution of research designs (n = 19)

Research Design	Number of Studies	Percentage	Reference
Quasi-experimental	14	73,7%	[7], [8], [10], [11], [12], [15], [16], [17], [18], [21], [22], [25]
Pre-experimental	3	15,8%	[9], [13], [23]
Descriptive	1	5,3%	[6]
Mixed-methods	1	5,3%	[20]
Research and Development (R&D)	1	5,3%	[24]
Qualitative literature review	1	5,3%	[19]
Total	19	100%	19

One study [18] used a true experimental design (pretest–posttest control group design) and was initially categorized separately from quasi-experimental studies; however, for consistency with the categorization used in the majority of the literature, this study was grouped under the quasi-experimental category in the table above.

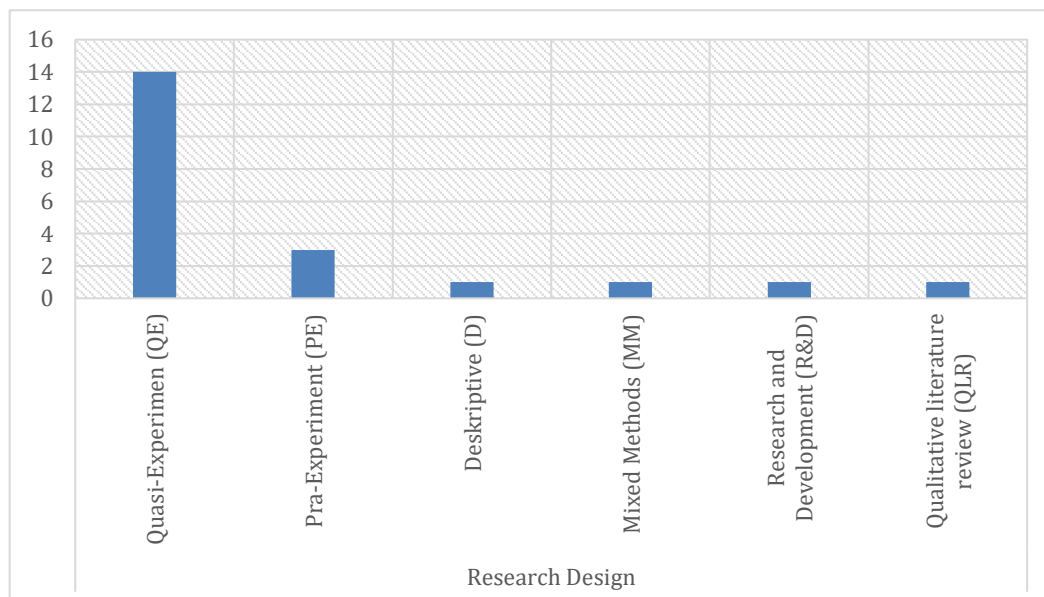


Figure 3. Types of research design

a) Quasi-Experimental Design Specifications

Table 3. Quasi-experimental design specifications

Research design	Number of study	Reference
Pretest-posttest non-equivalent control group design	7	[11], [15], [16], [17]
Pretest-posttest control group design	4	[7], [18], [21]
Nonequivalent control group design	1	[10]
Non-Equivalent Control Group Design	1	[8]
Static group comparison design	2	[22], [25]
Comparative (comparing two instructional models)	1	[12]

b) Pre-Experimental Design Specifications

Studies with pre-experimental designs in this review generally employed a one-group pretest–posttest design, involving only a single group without a comparable control group. In this design, students' science process skills are measured before and after the instructional intervention, and the difference in scores is then analyzed to determine whether an improvement has occurred.

Pre-experimental designs provide an initial indication of the potential effectiveness of a given instructional model, but they have limitations in controlling for confounding variables because no equivalent comparison group is included. In the context of SPS research, this means it is difficult to ascertain whether improvements in science process skills are solely attributable to the intervention or are influenced by other factors such as prior learning experiences, motivation, or environmental support.

c) Independent and Dependent Variables

Independent Variables

The majority of the studies investigated instructional models or approaches as the independent variable, with inquiry-based learning (guided, structured, and open inquiry) being the most common intervention [7], [10], [11], [12], [15], [16], [17], [18], [19], [21], [22], [24]. Other interventions included contextual learning [7], [23], POGIL model [8], CLIS model [9], blended learning [11], and virtual practice [13].

Dependent Variable

All studies measured science process skills as the primary dependent variable, including general SPS, basic SPS, and integrated SPS. Several studies also assessed additional dependent variables, such as learning outcomes. [21], scientific attitude [18], conceptual understanding [12], and collaboration skills [8].

d) Sampling Method

The sampling methods used in the reported studies encompassed several approaches. One of these was cluster sampling, which was employed in the study by Hardianti and Kuswanto [3]. In addition, cluster random sampling was employed in the study conducted by Bakti et al. [14]. Meanwhile, a saturated sampling approach was used in the study by Wulandari and Megawati [19]. However, most of the studies did not explicitly report their sampling methods, so information on sampling procedures could not be determined for those studies.

4) Synthesis of Data Analysis Methods

The data analysis methods used in the 19 included studies were predominantly quantitative, with inferential statistical tests and gain calculations being the most commonly applied techniques. The widespread use of t-tests and N-Gain calculations reflects a quantitative emphasis in Indonesian SPS research, although reporting of assumption tests, effect sizes, and use of statistical software remains limited, potentially affecting reproducibility. Table 4 presents the frequency of the data analysis methods employed.

Table 4. Frequency of data analysis methods (n = 19)

Data Analysis Methods	Number of Study	Percentage	Reference
Inferential statistical tests			
Uji-t (independent or paired)	11	57,9%	[2], [4], [5], [8], [12], [13], [14], [17], [18]
ANCOVA	2	10,5%	[1]
Kruskal-Wallis test	1	5,3%	[1]
Normality test	5	26,3%	[4], [17], [18]
Homogeneity test	4	21,1%	[4], [17]
Gain and effect size calculations			
N-Gain	8	42,1%	[7], [10], [15], [17], [18]
Effect size	3	15,8%	[4], [16]
Gain-score comparison	1	5,3%	[3]
Descriptive statistics			
Percentage	3	15,8%	[4], [19]
Mean	2	10,5%	[19]
Table, graphic, figure	2	10,5%	[19]
Observation sheet (Likert scale)	2	10,5%	[6], [13]
Qualitative analysis			
Qualitative interviews and observations	2	10,5%	[11], [12]
Thematic/content analysis	1	5,3%	[9]
Software			
SPSS v.24	1	5,3%	[13]
Not reported	18	94,7%	

a) t-Test as a Dominant Method

Independent and paired t-tests were the most commonly used statistical analysis methods, appearing in 11 of the 19 studies. (57,9%) [2], [4], [5], [8], [12], [13], [14], [17], [18]. Independent t-tests were used to compare SPS between experimental and control groups, whereas paired-samples t-tests were applied to compare pretest and posttest scores in one-group designs [18].

b) N-Gain Calculation

N-gain was used in 8 studies (42.1%) to quantify improvements in SPS from pretest to posttest, with gain values categorized as low, medium, or high [7], [10], [15], [17], [18]. This method is highly popular in the Indonesian education context for evaluating the effectiveness of instructional interventions.

c) ANCOVA and Non-Parametric Tests

Only one study used Analysis of Covariance (ANCOVA) to control for covariates [1]. The Kruskal–Wallis test, as a non-parametric alternative to ANOVA, was also used in the same study [1].

d) Assumption Test

Normality tests were reported in 5 studies (26,3%) [4], [17], [18], and homogeneity tests in 4 studies (21,1%) [4], [17]. However, the majority of studies did not explicitly report testing statistical assumptions, raising concerns about the validity of the parametric test results used.

e) Effect Size

Effect size calculations were reported in 3 studies (15.8%) [4], [16], de with effect size values ranging from 0.642 (large) to 1.5 (very large). Reporting of effect sizes remains relatively rare in SPS research in Indonesia, even though this information is important for evaluating the practical significance of interventions.

f) Descriptive Statistics

Descriptive statistics, such as percentages, means, tables, and graphs, were used in several studies, particularly in descriptive research [19] and as a complement to inferential analyses [4].

g) Qualitative Analysis

Only 3 studies integrated qualitative analysis, including interviews and observations, alongside quantitative approaches [11], [12], and thematic/content analysis in the literature review [9]. This indicates the dominance of quantitative approaches in SPS research in Indonesia.

h) Analysis Software

Only one study explicitly reported the use of statistical analysis software (SPSS v.24) [13]. Most studies did not report the software used, which may affect the transparency and reproducibility of the analyses.

i) Significant Level

Most studies reported statistical significance results (e.g., $p < 0,05$ or $p = 0,000$), but only a few explicitly stated the alpha

significance level predetermined before the analysis.

5) Measured Science Process Skills (SPS)

Table 5. Measured science process skills (SPS)

SPS Category	Skills Specification	Number of Study	Reference
Basic SPS			
	Observing	3	[6], [16], [19]
	Classifying	1	[6]
	Measuring	2	[6], [16]
	Concluding	3	[6], [16], [19]
	Predicting	2	[16], [19]
	Communicating	1	[19]
Integrated SPS			
	Formulating hypotheses	3	[10], [15], [6]
	Identifying variables	2	[6], [15]
	Designing experiments	2	[1], [10]
	Collecting data	1	[1]
	Presenting data	1	[1]
	Interpreting data	2	[10], [6]
	Analyzing data	1	[15]
	Discussing data	1	[1]
	Applying concepts	1	[10]
	Graphing	1	[6]
	Identifying relationships	1	[6]
General SPS			
	General (unspecified)	SPS 9	[2], [3], [4], [5], [7], [8], [12], [14], [17]

Several studies measured science process skills (SPS) in general without specifying individual skills, whereas other studies assessed specific skills at both the basic and integrated levels

a) General SPS vs. Specific SPS

Nine studies (47.4%) measured science process skills (SPS) in general without specifying the individual skills assessed [2], [3], [4], [5], [7], [8], [12], [14], [17]. This indicates that nearly half of the studies used holistic SPS instruments that measure science process skills as a single construct.

b) Basic SPS

The most frequently measured basic skill was observing (3 studies) [6], [16], [19], inferring (3 studies) [6], [16], [19], and measuring (2 studies) [6], [16]. Other basic skills, such as classifying, predicting, and communicating, were measured in fewer studies

c) Integrated SPS

The most frequently measured integrated skill was formulating hypotheses (3 studies) [10], [15], [6], identifying variables (2 studies) [6], [15], designing experiments (2 studies) [1], [10], and interpreting data (2 studies) [10], [6]. Other integrated skills, such as collecting data, presenting data, analyzing data, and applying concepts, were measured in only one or two studies.

d) Focus on Integrated SPS

Several studies explicitly focused on measuring integrated science process skills (SPS) [1], [10], which are considered higher-order skills that require the integration of several basic skills.

e) Measuring Instruments

The instruments used to measure Science Process Skills (SPS) included various forms, namely SPS tests with a pretest–posttest design [2], [3], [4], [5], [7], [12], [14], [17], observation sheets [4], [6], [8], [11], [13], essay questions [8], as well as combinations of tests and observations [11]. Nevertheless, most studies did not report validity and reliability data for the SPS instruments used, which constitutes a substantial methodological limitation in interpreting the research findings.

6) Interventions and Learning Models

The analysis of the interventions and instructional models investigated revealed the dominance of inquiry-based learning in SPS research in Indonesia. Table 5 presents the distribution of the learning models examined

Table 5. Learning models and instructional interventions investigated

Learning/Instructional Model and Intervention	Number of Study	Percentage	References
Inquiry-Based Learning (various levels).	11	57,9%	[1], [2], [3], [5], [7], [9], [12], [13], [14], [16], [17]
- Guided inquiry)	7	36,8%	[2], [5], [7], [9], [14], [16], [17]
- Structured inquiry)	1	5,3%	[1]

Learning/Instructional Model and Intervention	Number of Study	Percentage	References
- Open inquiry)	1	5,3%	[1]
- STEAM-based inquiry.	1	5,3%	[4]
- General inquiry (unspecified level)	3	15,8%	[3], [12], [13]
Contextual teaching learning (CTL)	2	10,5%	[2], [15]
POGIL (Process Oriented Guided Inquiry Learning)	1	5,3%	[8]
Model CLIS (Children's Learning in Science)	1	5,3%	[10]
Blended Learning	1	5,3%	[14]
Virtual laboratory practice. (Macromedia Flash)	1	5,3%	[18]
Experimental method	1	5,3%	[7]
Interactive e-module	1	5,3%	[9]

Some studies investigated more than one learning model or a combination of models, so the total percentage exceeds 100%

a) Dominance of inquiry learning

Inquiry-based learning was the most frequently investigated intervention, appearing in 11 out of 19 studies (57.9%) [1], [2], [3], [5], [7], [9], [12], [13], [14], [16], [17]. Guided inquiry is the most popular variant, used in 7 studies (36.8%) [2], [5], [7], [9], [14], [16], [17].

b) Inquiry level

One study explicitly compared the three levels of inquiry (structured, guided, and open) and found that open inquiry had the highest effectiveness for integrated science process skills, although there was no significant difference among the three levels in improving general science process skills [1].

c) Integration with other approaches

Several studies integrate inquiry-based learning with other approaches or technologies to enhance its effectiveness. One example is STEAM-based inquiry, which combines science, technology, engineering, art, and mathematics in the learning process [4]. In addition, inquiry was also combined with the CTL (Contextual Teaching and Learning) approach, which focuses on learning that is relevant to students' real-life contexts [2]. A guided inquiry-based blended learning approach was also implemented, combining face-to-face instruction with online learning to support the inquiry process [14]. In addition, the use of interactive guided inquiry-based e-modules is also becoming increasingly popular, enabling students to learn independently with structured guidance [9].

d) Other learning models

The non-inquiry learning models investigated include several approaches that focus on different methods and media. One of them is the POGIL (Process Oriented Guided Inquiry Learning) model, which uses animation media to support the learning process [8]. In addition, the CLIS (Children's Learning in Science) model was also included in this research, which focuses on a more structured approach to science instruction [10]. Contextual learning based on local wisdom was also explored as an effort to connect the subject matter with local cultural values [15]. Virtual laboratory activities using Macromedia Flash were explored as an alternative to replace traditional laboratory experiments [18]. Finally, the experimental method was compared with guided inquiry to evaluate the effectiveness of both approaches in teaching [7].

e) Effectiveness of intervention

Most of the studies reported that the instructional interventions examined were effective in significantly improving students' science process skills compared to conventional instruction or control groups [1], [2], [4], [5], [6], [7], [8], [12], [13], [14], [15], [16], [17]. However, one study reported a low effect of virtual laboratory activities on the growth of science process skills (N-Gain = 0.2) [18], and one study found that the experimental method did not significantly affect science process skills compared to guided inquiry. Satu studi menemukan bahwa metode eksperimen tidak signifikan mempengaruhi SPS dibandingkan dengan inkuiri terbimbing [7].

f) Duration of intervention

Most of the studies did not explicitly report the duration of the interventions, which is important information for evaluating the feasibility and practical effectiveness of the interventions.

B. Discussion

1) Dominance of Quasi-Experimental Designs

A key finding of this systematic review is the dominance of quasi-experimental designs in science process skills research in Indonesia, with 14 of 19 studies (73.7%) using this design [1], [2], [3], [4], [5], [6], [8], [12], [13], [14], [17]. This dominance is consistent with global trends in educational research, where quasi-experimental designs are often chosen for practical and ethical considerations in formal educational contexts [1], [3], [5]. Quasi-experimental designs allow researchers to investigate the effectiveness of learning interventions in realistic classroom settings without full randomization, which is often unfeasible or unethical in school contexts [2], [6], [14]. However, these designs have limitations in terms of internal validity due to potential selection bias and uncontrolled confounding variables [3], [17]. The majority of the reviewed studies used a pretest-posttest non-equivalent control group design, which provides better control over internal validity threats than pre-experimental designs, but is still not as robust as a true experimental design with randomization [1], [3], [5], [14].

Only one study used a true experimental design with randomization [7], indicating that SPS research in Indonesia still underutilizes designs with the highest internal validity. This limitation may be due to practical constraints in conducting randomization in schools, such as existing class structures, school policies, and ethical considerations [7]. Three studies used a pre-experimental design with a one-group pretest-posttest design without a control group [10], [15], [18]. This design has the weakest internal validity because it cannot

control for threats such as maturation, testing effects, and regression to the mean [10], [15], [18]. Although these designs can provide initial indications of the effectiveness of an intervention, the results of these studies should be interpreted with caution and require replication with more rigorous designs.

2) Data Analysis Method: Quantitative Approach

Analysis of research methods shows the dominance of quantitative approaches in the study of Student Professional Competence (SPC) in Indonesia, with the t-test as the most commonly used statistical method, found in 11 studies (57.9%) [2], [4], [5], [8], [12], [13], [14], [17], [18]. The extensive use of the t-test reflects the research focus on comparing SPC means between experimental and control groups, or between pretest and posttest [2], [5], [8], [14], [17]. In addition, the N-Gain calculation is also popular, appearing in 8 studies (42.1%) [7], [10], [15], [17], [18], as this method is commonly used in the Indonesian educational context to assess learning improvement by considering students' initial scores [7], [10], [15]. N-Gain provides information on the effectiveness of an intervention in improving SPS from baseline, with gains categorized as low (<0.3), moderate ($0.3-0.7$), or high (>0.7) [10], [15], [18].

However, several methodological limitations were identified. First, there was a lack of reporting of assumption tests, with only 5 studies (26.3%) reporting normality tests [4], [17], [18], and 4 studies (21.1%) reporting homogeneity tests [4], [17]. The majority of studies using parametric tests such as t-tests and ANCOVA did not include tests for normality and homogeneity of variance assumptions, raising questions about whether the prerequisites for validity of these tests were met [2], [5], [8], [12], [13], [14]. Second, reporting of effect sizes was limited, with only three studies (15.8%) including this information [4], [16], even though effect sizes are important for assessing the practical significance of interventions in addition to statistical significance and aiding in comparing effects across studies [4], [16]. Third, transparency regarding the use of analysis software was low; only one study explicitly reported the use of SPSS v.24 [13], thus affecting the reproducibility and verifiability of results. Finally, qualitative analysis was rarely used, with only three studies integrating it [9], [11], [12], indicating the dominance of quantitative approaches. Qualitative analysis can provide in-depth insights into the mechanisms of PPP development, the challenges of intervention implementation, and the contexts that support or hinder PPPs [11], [12]. The lack of rigorous mixed-methods studies represents a significant methodological gap in the PPP literature in Indonesia.

3) Distribution by Educational Level

The distribution of research on Science Process Competencies (SPC) by educational level shows a predominance at the senior high school level, with 9 studies (47.4%) [2], [3], [5], [7], [10], [14], [17], [18], followed by universities and junior high schools with 3 studies (15.8%) each [1], [6], [13] and [11], [12], [16], and 2 studies at elementary schools (10.5%) [8], [15]. The concentration at the senior high school level can be explained by several factors. First, the science curriculum in senior high schools is more complex and emphasizes scientific inquiry skills, making SPC development a clearer learning focus [2], [5], [7], [14], [17]. Second, senior high school students have more mature cognitive abilities to develop integrated and complex SPC [10], [17]. Third, research at the high school level is relatively easier to conduct because students are more independent and able to follow more complex research protocols [3], [18].

However, the limited research at the elementary school level, with only two studies [8], [15], presents a significant gap, considering that the development of basic science process skills should begin early in science education. Basic science process skills, such as observing, classifying, and measuring, can and should be developed in elementary school-aged children as a foundation for more complex skills at later levels [8], [15]. Therefore, further research is needed to understand effective strategies for developing science process skills in elementary school students in the Indonesian context. Research at the university level, with three studies [1], [6], [13], focuses on prospective teachers and science education students. This population is important because they will be the future educators responsible for developing students' science process skills. Findings indicate that inquiry-based learning is effective in developing prospective teachers' science process skills, which has significant implications for teacher education and professional development [1], [6], [13], [16].

4) Inquiry Learning Model

Inquiry-based learning has emerged as the most widely studied intervention in research on Science Process Skills (SPS) in Indonesia, reported in 11 studies (57.9%) [1], [2], [3], [5], [7], [9], [12], [13], [14], [16], [17]. Among the inquiry variants, guided inquiry is the most popular, appearing in 7 studies (36.8%) [2], [5], [7], [9], [14], [16], [17]. This dominance aligns with contemporary science education theories emphasizing active, student-centered, and investigation-based learning to develop SPS [1], [5], [7], [16]. Inquiry-based learning facilitates SPS development by providing students with direct engagement in scientific inquiry processes, including formulating questions, designing experiments, collecting and analyzing data, and drawing conclusions [1], [5], [12], [16]. Most studies report that inquiry-based learning significantly improves SPS compared to conventional instruction [1], [2], [5], [7], [12], [13], [14], [16], [17].

One study comparing three levels of inquiry structured, guided, and open found that open inquiry was the most effective for integrated SPS, although there were no significant differences in general SPS improvement among the three levels [1]. This finding suggests that higher-level inquiry, which provides greater student autonomy, may be more effective in developing advanced science process skills, while all inquiry levels outperform conventional learning [1]. Several studies also combine inquiry-based learning with other approaches or technologies, such as STEAM [4], Contextual Teaching and Learning (CTL) [2], blended learning [14], and interactive e-modules [9]. This integration reflects a trend toward more holistic and multimodal learning, leveraging the strengths of multiple pedagogical approaches [4], [9], [14]. For example, STEAM-based inquiry integrates science, technology, engineering, arts, and mathematics to provide authentic and interdisciplinary learning contexts [4], while guided-inquiry blended learning combines online and face-to-face instruction, offering flexibility and personalized learning [14]. Despite these benefits, challenges remain. One study reported that virtual laboratories using Macromedia Flash produced only a low effect on SPS growth (N-Gain = 0.2) [18], indicating that not all technology implementations are equally effective. Factors such as instructional design quality, teacher support, and student engagement strongly influence the effectiveness of inquiry-based interventions [18].

5) Methodological Limitations in the Reviewed Studies

Several methodological limitations were commonly identified in the reviewed studies, which warrant careful consideration. First, sample sizes in some studies were relatively small (e.g., 20–30 participants) [10], [15], [19], potentially reducing statistical power to detect significant effects and limiting the generalizability of findings. Additionally, seven studies did not report sample sizes explicitly [2], [3], [4], [11], [12], [14], which is essential information for assessing the validity and reliability of results. Many studies also lacked comprehensive methodological reporting, including details on sampling methods, instrument validity and reliability, intervention procedures, and statistical assumption testing [2], [3], [4], [8], [12]. This lack of transparency hampers the evaluation of study quality and reproducibility. Furthermore, most studies did not report the validity and reliability of the SPS instruments used [2], [3], [4], [5], [7], [8], [12], [14], [17], making it difficult to determine whether the measures accurately and consistently assessed science process skills. In addition, intervention duration was often unspecified, limiting understanding of practical feasibility and the dosage required to achieve meaningful SPS improvements.

Control of potential confounding variables was another major limitation. Many quasi-experimental studies did not address factors such as students' prior ability, motivation, parental support, or teacher quality [2], [3], [5], [8], [12], [14], and only one study applied ANCOVA to account for covariates [1]. External validity was also restricted, as most studies were conducted in highly specific contexts (single schools or a few schools in one city), limiting generalizability [2], [5], [7], [8], [10], [14], [15], [18]. Multi-site studies with more diverse samples are needed to strengthen external validity. Finally, all reviewed studies were cross-sectional or short-term interventions without long-term follow-up, and no longitudinal research examined SPS development over time or retention after the intervention. Longitudinal studies are essential to understand the trajectories of SPS development and the sustainability of intervention effects.

6) Implications for Research and Practice

Findings from this systematic review have several important implications for both future research and educational practice. For research, there is a need to diversify study designs by exploring true experimental designs with randomization where feasible, longitudinal studies to track SPS development over time, and rigorous mixed-methods approaches that integrate quantitative and qualitative perspectives [7], [11], [12]. Improving methodological reporting is also critical, including details on sampling, sample size, instrument validity and reliability, intervention procedures, statistical assumption testing, and effect size calculations [1], [4], [16]. Standardized, valid, and reliable SPS measurement instruments adapted to the Indonesian context are urgently needed to facilitate comparison across studies and support future meta-analyses. Additionally, future studies should investigate not only intervention effectiveness but also the mechanisms through which interventions influence SPS development, using qualitative or mixed-methods designs to uncover cognitive, social, and pedagogical processes [11], [12]. Expanding research to underexplored educational levels, particularly elementary schools [8], [15], and to diverse geographical contexts across Indonesia, is essential for enhancing the generalizability of findings.

For educational practice, the robust evidence supporting the effectiveness of inquiry-based learning in developing SPS underscores the need for broader implementation of this approach in Indonesian science classrooms [1], [2], [5], [7], [12], [13], [14], [16], [17]. Teachers should receive adequate training and support to implement inquiry-based instruction effectively. Findings that inquiry-based learning benefits pre-service teachers [1], [6], [13], [16] highlight the importance of integrating such approaches into teacher education programs and ongoing professional development. Technology integration, including interactive e-modules, blended learning, and virtual labs, shows potential to enhance SPS, though effectiveness depends on quality design and implementation [9], [14], [18]. SPS assessment should be embedded in science education, with valid and reliable instruments used consistently, while contextualized learning that incorporates local knowledge and students' real-life experiences has proven effective in making science learning meaningful and relevant [2], [15]. Together, these implications point to a research-informed and context-sensitive strategy for fostering SPS across Indonesian classrooms. These findings align with international trends where quasi-experimental designs dominate educational research due to practical and ethical constraints. However, the limited use of true experimental, longitudinal, and mixed-methods designs indicates a gap in methodological rigor compared to global standards. While guided inquiry consistently improves SPS, the lack of diverse study designs and standardization of instruments limits generalizability and comparability across studies.

4. Conclusion

The findings from this systematic review highlight several key insights regarding Science Process Skills (SPS) research in Indonesia. The majority of studies employed quasi-experimental designs, particularly pretest-posttest non-equivalent control group designs, and relied predominantly on quantitative data analysis methods such as t-tests and N-Gain calculations, while qualitative and mixed-methods approaches remain limited. Research was heavily concentrated at the high school level, with inquiry-based learning especially guided inquiry emerging as the most widely studied intervention, demonstrating consistent effectiveness in enhancing SPS across various skill dimensions, including observation, hypothesis formulation, and experimental design. Despite these strengths, the review identified significant methodological limitations, including small sample sizes, incomplete reporting of methodology, lack of instrument validity and reliability evidence, absence of statistical assumption testing, limited reporting of effect sizes, and a scarcity of longitudinal or rigorous mixed-methods studies.

Based on these findings, future research should aim to diversify study designs by incorporating true experimental designs with randomization, longitudinal studies to track SPS development and retention, and rigorous mixed-methods studies to integrate quantitative and qualitative insights. Methodological rigor should be improved through larger sample sizes, complete and transparent reporting, the use of advanced statistical controls for confounding variables, and consistent reporting of effect sizes to facilitate practical interpretation and future meta-analyses. Standardized, valid, and reliable SPS measurement instruments tailored to the Indonesian context are also essential, alongside exploring SPS development in under-researched educational levels, particularly elementary schools, and across diverse geographical and instructional contexts. Additionally, investigations should focus on the mechanisms and processes underlying SPS development, as well as the integration of emerging technologies and interdisciplinary

approaches such as STEM/STEAM to support learning innovations.

For educational practice, the review recommends broader implementation of inquiry-based learning as a primary approach in science education, supported by continuous teacher training and the development of instructional resources such as practical guides, digital modules, and e-learning platforms that facilitate online inquiry activities and SPS assessment. Pre-service teacher programs and ongoing professional development should integrate inquiry-based pedagogy together with the design of project-based, collaborative, and technology-enhanced learning experiences so that future educators are able to orchestrate both face-to-face and online investigations effectively. Assessment of SPS should be incorporated into routine science evaluation, using valid and reliable instruments that can be administered in classroom and e-learning environments, while schools invest in laboratories, virtual simulations, and other digital resources to support sustained inquiry. Curricula and policies should explicitly emphasize SPS development at all education levels by embedding inquiry-oriented projects that require students to work collaboratively on real-world problems, document their findings digitally, and reflect on both process and outcomes. Contextualized learning that incorporates local wisdom such as local environmental issues, traditional technologies, or cultural practices should be promoted so that projects and inquiries are grounded in students' communities, thereby enhancing relevance, engagement, and cultural identity. Finally, collaboration between schools, universities, research institutions, and industry can provide authentic project-based and community-linked learning experiences (including e-learning collaborations and joint field projects), strengthening both research and practice in SPS development while supporting 21st-century skills such as critical thinking, collaboration, and problem solving.

Future SPS research in Indonesia should diversify study designs by incorporating true experimental designs with randomization, longitudinal studies to assess skill retention, and mixed-methods approaches integrating quantitative and qualitative data. Methodological rigor must be improved through complete reporting of sampling, instruments, statistical assumptions, and effect sizes. Standardized, valid, and reliable SPS measurement tools adapted to the Indonesian context are urgently needed. Research should also expand to underrepresented educational levels, particularly elementary schools, and geographically diverse contexts. Finally, integration of technology and interdisciplinary approaches such as STEAM can enhance SPS development.

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