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SCIENCE PROCESS SKILLS IN SCIENCE LEARNING: A CURRENT SYSTEMATIC REVIEW

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ABSTRACT

A mastery of scientific process skills is a crucial foundation for developing scientific thinking and supporting 21st-century learning. This study employs a Systematic Literature Review (SLR) to examine the level of science process skills in science learning among primary school students in Malaysia. The SLR process involved four main steps: setting the objectives, searching for articles from databases such as Web of Science (WOS), Pro Quest, and ERIC, selecting relevant studies, and conducting a critical analysis of the findings. A total of 20 articles published between 2020 and 2025 were analyzed. The findings reveal that students' mastery of basic science process skills is at a moderate level, whereas their integrated science process skills remain low. Although students demonstrated a positive interest in inquiry-based learning activities, several challenges persist, including teachers' pedagogical constraints, limited teaching resources, and a lack of student-centred approaches. These findings highlight the need for focused intervention strategies that foster the holistic development of science process skills through creative, interactive, and contextual teaching methods. This study provides valuable insights for educators, researchers, and policymakers in designing science education interventions, thereby supporting the transformation of primary school learning towards a more innovative and competitive direction.

Keywords: science process skills, primary school students, science learning, systematic literature review

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INTRODUCTION

Science process skills (SPS) are one of the fundamental components of science education, as they form the foundation of scientific thinking and enable students to understand, apply, and construct scientific knowledge meaningfully. The skills of observing, classifying, inferring, predicting, measuring, and communicating are significant for developing inquiry-based learning, curiosity, creativity, and problem-solving skills among learners (Harlen, 2000). In the context of the Malaysian Primary School Standard Curriculum (Kurikulum Standard Sekolah Rendah (KSSR), the mastery of SPS is emphasized for producing students who could think scientifically, and apply reasoning in daily life (Ministry of Education Malaysia, 2017).

A high academic achievement is not only contributed by the mastery of scientific skills, but also by the cultivation of logical and evidence-based thinking to scientifically literate the society (Habibah & Shaharom, 2006). Nevertheless, studies indicate that Malaysian students still face difficulties in mastering SPS, such as low curiosity, limited inquiry skills, and difficulty in linking scientific concepts to real-life experiences (Kamisah et al., 2007; Zol Azlan, 2000). Additionally, science is often perceived as a difficult and exclusive subject, which contributes to declining student interest and engagement (Subahan, 1997; Razila, 1998; Ruhizan, 1999). These challenges led to concerns regarding the effectiveness of current pedagogical approaches in fostering scientific thinking among primary school students.

Other than the cognitive aspects, SPS are also linked to affective and moral dimensions of science learning. The values such as honesty, responsibility, and perseverance are embedded within the practice of scientific inquiry, and play a crucial role in shaping ethical and evidence-based reasoning (Lederman et al., 2002; Yaakob et al., 2015). Nevertheless, studies debate that such values are inconsistently assessed, and their integration within classroom practices remains limited (Mohd Satar et al., 2020).

Despite numerous studies exploring science process skills in Malaysian classrooms, it has been descriptive or localized in nature, focusing on specific teaching strategies and student attitudes rather than providing a comprehensive synthesis of existing evidence. This would lead to a limited understanding of overall trends, gaps, and effective practices related to SPS development among primary school students. Due to these issues, a systematic literature review is significant to consolidate current research on science process skills in Malaysian primary schools. This review aims to analyze existing studies, identify key patterns and challenges, and provide insights into effective strategies for strengthening science learning through SPS.

LITERATURE REVIEW

The Primary School Standard Curriculum (KSSR) for Science in Malaysia is structured around three main domains including knowledge, skills, and values. The domains are integrated through an inquiry-based learning approach aimed at cultivating students who think scientifically. Other than memorizing facts, the curriculum of science education should emphasize developing SPS, including observing, classifying, inferring, predicting, measuring, and communicating (Ministry of Education Malaysia, 2017). Based on the inquiry approach, students are encouraged to explore and investigate scientific phenomena, construct their own understanding, and apply reasoning in solving real-world problems. This approach reflects that science learning should engage students in the processes of generating knowledge.

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Science process skills are essential for the foundation of scientific thinking and the comprehension of scientific concepts effectively. Harlen (2000) discussed that the acquisition of these skills would allow learners to experience science as a process rather than isolated content. For Malaysian context, Habibah and Shaharom (2006) emphasized that mastery of scientific skills is vital for improving academic achievement and nurturing a culture of logical and evidence-based reasoning. Students who develop strong SPS are highly prepared to apply knowledge in daily life situations, and to think critically and creatively with the competencies required for the 21st-century.

The inquiry-based pedagogy outlined in the KSSR framework incorporates elements of student-centred learning, constructivism, contextual learning, problem-based learning, and mastery learning. These approaches promote active participation where students are encouraged to question, observe, experiment, and draw conclusions. Lederman et al. (2002) and Osborne, Simon, and Colline (2003) highlighted that authentic inquiry experiences promote the development of curiosity, persistence, and the ability to critically evaluate evidence among learners. Furthermore, teachers who consciously integrate scientific values, including honesty, responsibility, cooperation and openness to evidence into lessons, can foster a more ethical and reflective scientific mindset among learners (Mohd Satar et al., 2020). However, studies suggest that these values are often conveyed implicitly rather than systematically embedded in classroom instruction, which leads to inconsistencies in their application.

Despite emphasizing the science process skills in the curriculum, most Malaysian students continue to face challenges in mastering them. Kamisah et al., 2007 and Zol Azlan, 2000 have shown that students often struggle to relate scientific concepts to their everyday experiences, lack curiosity, and have difficulty forming hypotheses or making predictions during investigations. Besides, negative attitudes towards science remain prevalent, with students perceiving it as a difficult and exclusive subject reserved for high-achieving learners (Subahan, 1997; Razila, 1998 and Ruhizan, 1999). These perceptions could discourage engagement and the development of higher-order thinking skills for scientific reasoning. Science process skills are also closely related to students' attitudes, moral values, and interest in learning. Engaging in hands-on experiments and inquiry activities can nurture curiosity, persistence, and intrinsic motivation to explore scientific ideas. Yaakob et al. (2015) found a positive correlation between values of honesty, responsibility and students' scientific thinking styles. However, these values were inconsistently sustained beyond classroom contexts. Similarly, Ismail and Khairuzaman (2010) reported that a lack of genuine interest in science remains a major factor affecting students' ability to master the subject. The findings indicate that effective science learning requires teaching of process skills, and cultivation of positive attitudes and emotional engagement.

Previous research on science process skills in Malaysia has largely been described with limited empirical evidence linking teaching practices and value integration with that of student outcomes. For example, Kamisah and Wan Zah (2012) outlined important scientific values and attitudes, but there is no empirical evidence regarding the relationship with students' mastery of SPS. Besides, there is a lack of systematic studies to evaluate how effectively Malaysian primary education develops these skills. This gap in the literature highlights the need for a systematic literature review that synthesizes available evidence on the teaching and learning of science process skills among primary school students in Malaysia.

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In conclusion, science process skills play a central role in achieving the goals of the Malaysian primary science curriculum. They bridge the gap between conceptual understanding and the development of scientific thinking, fostering inquiry, creativity, and problem-solving abilities. However, challenges in pedagogy, values integration, and students' perceptions of science remain limited to effective learning. Therefore, reviewing and synthesizing existing research is essential to identify effective practices, highlight current limitations, and provide recommendations for strengthening science education in Malaysian primary schools.

METHODOLOGY

This study employed a systematic literature review (SLR) approach to identify, evaluate, and synthesize existing research related to SPS in science learning among primary school students in Malaysia. A systematic review provides a structured and transparent process for gathering evidence using explicit criteria and methods designed to minimize bias, thus producing reliable and replicable findings. The review followed four major stages, namely planning, conducting the search, screening and selection, and synthesizing the findings. The methodological framework for this review was adapted from the approaches outlined by Breckwoldt et al. (2021) and Bannuru et al. (2014), ensuring that each stage adhered to the standards of systematic inquiry and quality assessment (see Figure 1).

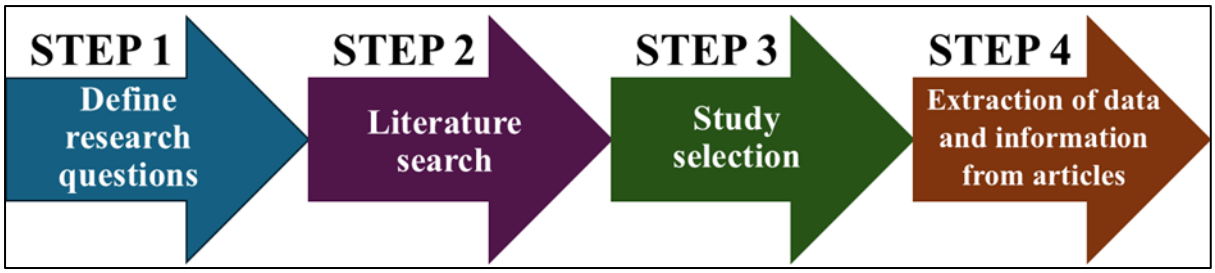

Figure 1. Four steps in the analysis of a systematic literature review.

Step 1: Define Research Questions

The planning stage began with the formulation of clear and focused research questions. The PICO framework (Population, Intervention, Comparison, and Outcome) was adapted to guide the review process. In this study, the population referred to primary school students in Malaysia; the intervention represented teaching and learning approaches that emphasize SPS; the comparison focused on traditional or alternative approaches not explicitly centred on SPS; and the outcome involved students' mastery, attitudes, motivation, and performance in science learning. Based on this framework, the review was guided by three research questions:

(i) What is the current state of research on SPS among primary school students in Malaysia?
(ii) What methods and strategies have been used to develop and assess SPS in primary science education?
(iii) What are the key findings, challenges, and research gaps identified in existing studies?

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Step 2: Literature Search

A comprehensive search strategy was then implemented across major databases, including Web of Science (WOS), ProQuest, and ERIC. These databases were chosen due to their broad coverage of educational and scientific research. The search was limited to studies published between 2020 to 2025 to capture the most recent five years of research relevant to the Malaysian education system. Boolean operators and keyword combinations such as "Science Process Skills" OR "Scientific Skills," AND "Primary School" OR "Elementary Education," AND "Malaysia" OR "Malaysian Students," AND "Science Learning" OR "Science Education" were used to refine the search results. Only peer-reviewed journal articles, academic theses, and conference proceedings published in English or Malay were included, while review papers and studies unrelated to Malaysian primary schools were excluded. All references retrieved were imported into the EndNote reference management software to organize the articles and remove duplicates systematically.

Step 3: Study Selection

The screening and selection process involved three phases: title screening, abstract review and full-text evaluation. Studies were assessed for their relevance to the research objectives based on inclusion and exclusion criteria. The inclusion criteria consisted of studies that focused on SPS and constructs such as scientific inquiry and process-oriented learning, were conducted in Malaysian primary schools, were empirical in nature (quantitative, qualitative, or mixed-method), and were published within the specified time frame. Excluded studies were those unrelated to Malaysian primary education, purely theoretical papers without empirical data, and non-peer-reviewed publications. The initial search yielded a total of 432 records. After removing duplicates and applying the inclusion criteria, 17 studies (WOS database), 40 studies (ProQuest database), and 25 studies (ERIC database) were selected for detailed analysis and synthesis.

Step 4: Extraction of Data and Information from Articles

The data extraction process was conducted to identify and systematically record key information from the selected articles. After study secelction process, several studies (n=20) were selected and considered for qualitative synthesis. In the final stage, data were extracted and synthesized systematically. Key information from each study, including the author, year of publication, research objectives, sample, methodology, instruments, and main findings, was tabulated and organized into a synthesis matrix. The data were then analyzed thematically to identify emerging trends, key themes, and research gaps. Thematic analysis focused on four primary aspects: (i) types and classifications of SPS assessed in the studies, (ii) teaching and learning strategies used to develop SPS, (iii) assessment methods and tools applied to measure SPS, and (iv) challenges and recommendations for improving SPS among primary students. The review process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency, reproducibility, and credibility. This systematic approach enabled a comprehensive understanding of how SPS have been explored, implemented, and evaluated in Malaysian primary science education. The detailed review and analysis process was adapted from established frameworks by Moher et al. (2009) and Shaffril et al. (2018), as illustrated in Figure 2.

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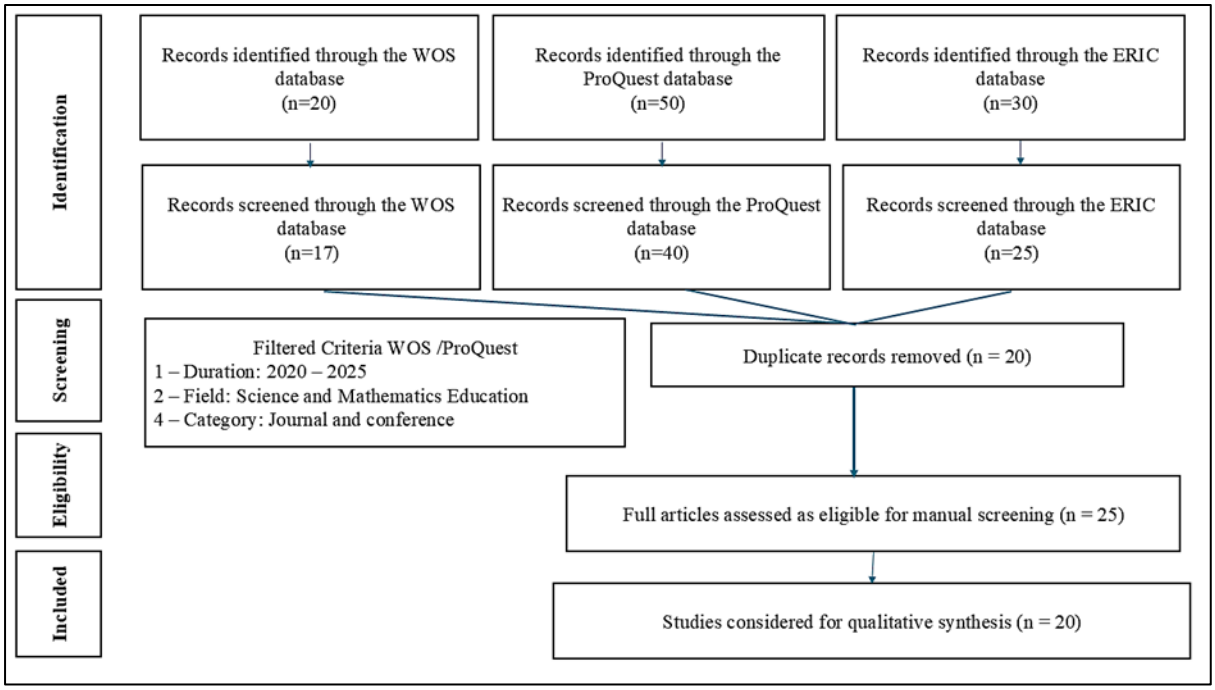

Figure 2. The process of reviewing and analyzing articles.

In brief, the PRISMA flow diagram illustrates the process through which 82 initial studies were narrowed down to 20 relevant studies. This process involved the removal of duplicates, followed by the screening of titles, then abstracts, and subsequently full-text articles, ultimately resulting in 20 studies that are relevant and aligned with the research topic. Figure 3 presents this flow process.

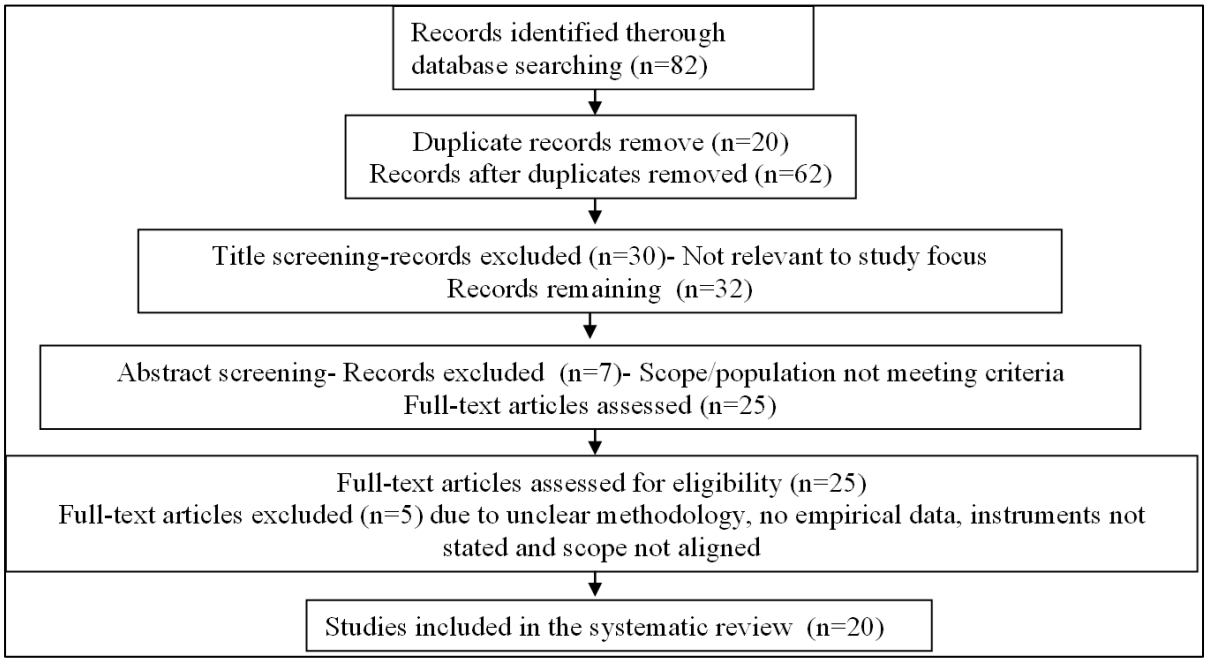

Figure 3. The PRISMA flow diagram illustrates the process of 82 initial studies narrowed down to 20 relevant studies.

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Quality Assesment

To ensure the accuracy and reliability of the studies included in this review, each study was assessed for quality using the following criteria: (i) the appropriateness of the study design in addressing the research questions, (ii) transparency and rigor of data collection procedures, (iii) validity and reliability of the instruments used, and (iv) clarity in reporting study findings. Quality assessment was conducted independently by two reviewers to minimize bias, with any discrepancies resolved through discussion or consultation with a third reviewer.

Out of the 82 initially identified studies, five studies were excluded due to failing to meet the minimum quality criteria, primarily related to unclear methodology and incomplete data reporting. The quality assessment also informed the data synthesis process, with higher-quality studies given greater emphasis in the thematic analysis and comparative evaluation. This approach ensured that the data synthesis was based on robust and relevant evidence aligned with the research objectives.

RESULTS AND DISCUSSION

The twenty studies share certain similarities which are categorized into two key aspects: the methodologies employed, and the similarities in the content. Table 1 summarises the twenty studies that were identified and subsequently analysed.

Table 1. Analysis of studies from 2020 to 2025

No.	Researcher / Year	Sample / Location	Research Objective	Research Design	Main Findings
1	Nazahiyah Mustafa, Ahmad Zamri Khairani, Nor Asniza Ishak (2021)	128 Year 5 pupils, one primary school in Penang, Malaysia	To calibrate science process skills (SPS) test items and determine the level of item difficulty using the Rasch model.	Quantitative; partial credit test; Rasch model analysis.	Found that *observing* and *communicating* were the easiest skills, while *inferring* and *classifying* were the most difficult for primary pupils.
2	Eng Tek Ong et al. (2022)	348 pupils (Years 4–6) from urban Malay and Orang Asli primary schools, Malaysia	To identify the overall mastery level of basic SPS and compare between ethnic groups (Malay vs Orang Asli).	Quantitative; BSPS test with 36 multiple-choice items; descriptive and inferential analyses (t-test, ANOVA).	Malay pupils achieved an "acceptable" level in *classifying* (~71.12%) and *predicting* (~67.43%), while Orang Asli pupils did not reach acceptable levels for any skills; significant differences found by grade level among Malay pupils.
3	Ahmad, N. F. & Zanaton Iksan (2021)	Primary school pupils	To explore how digital science games help	Quantitative (pre-test and post-test design); digital	Pupils showed improvement in SPS after the digital game

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No.	Researcher / Year	Sample / Location	Research Objective	Research Design	Main Findings
		(exact number not specified; location not stated).	promote pupils' SPS in science learning.	game used as an instructional intervention.	intervention—especially in *observing, classifying, communicating,* and *inferring.*
4	Mohd. Munir Baharom, N. A. Atan, M. Rosli, S. Yusof, Mohd Zolkifli Abd Hamid (2020)	30 Year 6 students, Johor Bahru	To examine effectiveness of IBSE apps in improving SPS	Quasi experimental, time series	IBSE apps significantly improved SPS mastery and achievement
5	Hamidah Mat, S. S. Mustakim, Fazilah Razali (2025)	280 Year 5 students, Malaysia	To examine proficiency of higher order thinking skills (HOTS) in science	Survey, stratified sampling	Moderate HOTS proficiency; gaps in independent application and creative problem solving
6	Nuraini Abu Bakar; Siti Salina Mustakim; Aminuddin Hassan; Fazilah Razali. (2021)	12 Year 5 students,	To identify the dominant Science Process Skills (SPS) practiced by pupils during science lessons based on classroom assessment.	Qualitative research using triangulation method.	Most pupils have not yet mastered integrated SPS, reflecting gaps in comprehension and classroom application. Emphasizes the need for better instructional strategies and assessment alignment to strengthen integrated SPS development.
7	Hamizah Yaakob et al., (2023)	98 sixth-grade (Year 6) students from rural schools in the Jengka Zone (Malaysia).	To identify and examine the challenges faced by rural primary school students in learning Science subjects.	Quantitative research design.	1. Negative attitudes toward Science -the most significant challenge affecting achievement. 2. difficult to fully understand Science topics, indicating cognitive and conceptual gaps. 3. Struggled to apply experimental findings to everyday life 4. negatively affected classroom performance, concentration, and interest in Science.
8	Kamarudin, M. Z., & Mat Noor, M. S. A. (2024)	Rural primary school pupils in Malaysia.	To enhance science learning through a digital inquiry-based approach.	Action research. Digital inquiry activities, interest questionnaire, and SPS test.	Pupils were more motivated and showed improvement in basic SPS.

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No.	Researcher / Year	Sample / Location	Research Objective	Research Design	Main Findings
9	Arifin, Z., et al. (2024).	Primary and secondary school students.	To assess the effect of Inquiry-Based Learning (IBL) on critical thinking and SPS.	Experimental study. SPS test and critical thinking test.	IBL improved both SPS and critical thinking skills. IBL is suitable for developing scientific thinking among 21st-century learners.
10	Ong Eng Tek & Shamalah Manikam (2022)	379 students (upper primary, Indian students)	This study aims to compare the mastery level of basic science process skills among upper primary Indian students by gender, school location, and by grade levels.	Quantitative- Using an established 36-item Basic Science Process Skills (BSPS) test that assesses the skills of observing, communicating, classifying, measuring, predicting, and inferring with appropriate reliability and validity,	-urban Indian students achieved significantly higher than rural Indian students in overall BSPS and across all specific BSPS; - Year 6 Indian students achieved significantly higher than Year 4 and Year 5 Indian students except for classifying in which there was no significant difference between Year 6 and Year 5 Indian students
11	Mohd Yahya et al (2024)	Primary	This systematic literature review investigates strategies and findings to enhance science process skills, design thinking, and inquiry-based learning in primary education	Articles analysis, Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Framework	The results highlight the effectiveness of innovative pedagogy, technology-rich environments, scaffolding, and differentiated instruction.
12	Thiyagu Karupaiah & Esther Gnanamalar Sarojini Daniel (2021)	9 primary school students	To enhance low-achieving Year Five pupils' SPS specifically in: 1. Controlling variables **2.** Formulating hypotheses -using online tools.	Mixed Method- Quantitative and Qualitative -Action Research	The majority of low-achieving pupils showed improvement in science process skills • Peer collaboration with high-achieving students through synchronous online sessions (video call) effectively enhanced pupils' ability to control variables and formulate hypotheses.
13	Abdullah Abdul Halim & Noor	20 Year 5 primary	1) To design online learning	Quantitative, pre-experimental	Descriptive: Mean scores improved in both

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No.	Researcher / Year	Sample / Location	Research Objective	Research Design	Main Findings
	Dayana Abdul Halim (2024)	school pupils in Malaysia (online science learning via Telegram)	activities integrated with a heutagogy approach via Telegram. 2) To investigate the effect of the online heutagogy-based learning (via Telegram) on pupils' science process skills. 3) To investigate the effect on pupils' creative thinking skills.	(one group pre-test / post-test) design.	science process skills (pre-test mean ~17.00% → post-test mean ~38.50%, an improvement of ~21.50%) and creative thinking skills (pre-test mean ~27.00% → post-test mean ~43.25%, an improvement of ~16.25%). Inferential: Significant differences between pre- and post-test scores for both skills using the Wilcoxon signed-ranks test (science process skills: Z = –3.938, p < .001; creative thinking skills: Z = –3.631, p < .001)
14	Ellyza Karim, Syakima Ilyana Ibrahim, Hanani Harun Rasit, Bambang Sumintono (2024)	300 primary school leavers (aged 13 years, recently completed primary education).	- The aim was to ensure that the instrument accurately measures latent constructs of SPS among Malaysian primary school students.	Quantitative study	Construct validity: Instrument successfully measures latent SPS constructs. Skill mastery insights: Only 11% of students could design scientific steps independently (experimenting skill). The space-time relationship skill was rated most strongly mastered.
15	Norlaila Ariffin et al (2023)	30 primary school student	to design science learning activities that can help the students' understandingbe clearer and further support the mastery of KPS	quasi-experimental	The study's findings found a significant effect on the student's achievement before and after the science learning treatment with the integration of APS-TeWeV, and further helped in the mastery of the students' science process skills to a better level. The students's perceptions show a positive interest and acceptance towards learning science with the

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No.	Researcher / Year	Sample / Location	Research Objective	Research Design	Main Findings
					joint use of visual media through web technology
16	Hamidah Mat et al., (2025)	6 primary school science teachers	To identify and analyze the need for developing specialized teaching modules in primary science (specifically electrical topics) that aim to enhance students' higher-order thinking skills (HOTS)**.**	Approach: Qualitative research methodology.	Four major themes emerged: (1) Importance of HOTS knowledge, (2) Obstacles in teaching HOTS, (3) Effective teaching strategies, (4) Actual teaching of HOTS.
17	Thiyagu Karupaiah & Salmiza Saleh (2025)	5 Year 4 science teachers, Malaysian primary schools.	To identify teachers' needs for developing a design thinking-based STEM module that supports critical and creative thinking in Year 4 science instruction.	Qualitative; semi-structured interviews with teachers; thematic analysis.	Key needs identified include teacher training support, appropriate teaching resources, ICT adaptation, and integration of design thinking to enhance higher-order and scientific process skills among pupils.
18	Engku Mohd Sharul Akimi & Mohd Effendi (2024)	Not applicable (theoretical paper; no empirical data collected)	To explain the concepts of science process skills and manipulative skills in science learning, and to examine learning strategies that can enhance mastery of these scientific skills.	Conceptual design using literature review and theoretical discussion. Focuses on synthesizing previous studies and proposing strategies rather than testing hypotheses.	Three main strategies were identified to improve science process and manipulative skills: 1. Inquiry-Based Learning (IBL) 2. Scientific Argumentation-Based Learning (SABL) 3. Use of Information and Communication Technology (ICT) in science learning.
19	Mohd Syaubari et.al., (2023)	Participants**:** 402 primary school Science teachers	To assess the implementation of teaching Science among elementary school teachers through the integration of High-Level Thinking Skills	Quantitaive Design Type: Descriptive research design Data Collection Method: Questionnaire survey	-the implementation of KBAT in Science teaching is at a high level.

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No.	Researcher / Year	Sample / Location	Research Objective	Research Design	Main Findings
			based on the Kurikulum Standard Sekolah Rendah (KSSR).		
20	Santhira A/P Poongavanan et. al (2024).	30 year 5 strudents.	-to develop an Augmented Reality (AR) application with (5E) inquiry-based learning approach, -to improve students' spatial visualization skills and performance in science	Quantitative Pre experimental design	the findings proved that the AR application with an inquiry-based learning approach could improve students' spatial visualization skills and enhance their science learning outcomes

Analysis of the Methodology Implemented

Based on the analysis of 20 selected studies (see Table 1), research on the SPS among Malaysian primary school students demonstrates considerable methodological diversity, reflecting the complexity of science learning processes. Quantitative research designs dominate the field, particularly in studies that aim to measure the mastery level of basic or integrated SPS through standardized testing and psychometric approaches. Table 2 below presents a summary of the findings regarding the methodological approaches used in the analysed studies.

Table 2. Summary of the research design employed.

Research Design	Percentage (%)	Examples of instruments
Quantitative	55	BSPS test based on the Rasch model; quasi-experimental design
Mixed methods	25	Pre- and post-test combines with interviews; classroom video recordings
Qualitative	20	Teaching observations; document and analysis of instructional practices

Mustafa et al. (2021) and Ong et al. (2022) employed Rasch Measurement Models and multiple-choice Basic Science Process Skills (BSPS) tests to calibrate item difficulty and determine students' proficiency levels. Similarly, Karim et al. (2024) developed and validated a new SPS instrument using Rasch analysis, reporting high reliability and construct validity. These quantitative approaches provide objective data that allows researchers to identify specific SPS competencies (observing, communicating, and classifying) to more abstract skills like inferring or hypothesizing.

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In addition to measurement-oriented research, a few studies employed quasi-experimental or pre-experimental designs to assess the effectiveness of pedagogical interventions aimed at enhancing SPS. Ahmad and Iksan (2021) integrated digital science games into classroom learning and found notable improvements in pupils' ability to observe, classify, and communicate scientific ideas. Poongavanan et al. (2024) develop an Augmented Reality (AR) application with (5E) inquiry-based learning approach to improve students' spatial visualization skills and performance in science. Similarly, Baharom et al. (2020) adopted a quasi-experimental time-series design to evaluate the impact of Inquiry-Based Science Education (IBSE) applications, which significantly improved students' SPS mastery. Ariffin et al. (2023) found a significant effect on the student's achievement before and after the science learning treatment with the integration of APS-TeWeV, and further helped in the mastery of the students' science process skills to a better level. While Abdul Halim and Abdul Halim (2024) also demonstrated significant pre- and post-test gains in SPS and creative thinking when employing a heutagogy-based learning approach via Telegram. These intervention-based studies emphasize the positive role of technology and inquiry-oriented pedagogies in strengthening scientific reasoning and process skills among primary learners.

Several studies also adopted qualitative and mixed-method approaches, highlighting the contextual and behavioral dimensions of SPS learning. Abu Bakar et al. (2021) employed triangulation through classroom observations and interviews, using NVivo software for thematic analysis, to explore how pupils develop integrated SPS in real classroom settings. Similarly, Karupaiah and Saleh (2025) conducted semi-structured interviews with teachers to identify needs for integrating design thinking into STEM-based modules that enhance SPS and higher-order thinking skills. These qualitative approaches provide rich insights into teacher practices, pupils' learning challenges, and classroom realities that are not captured through quantitative measurement alone.

While Ahmad and Iksan (2021) reported significant improvments in SPS through digital games, Abu Bakar et al. (2021) found that students still struggle with integrated SPS despite active learning approaches. This suggests integrated SPS require higher-order thinking levels that are more challenging for primary school students and requires more structured and scaffolded instructional support.

Meanwhile, Karupaiah and Daniel (2021) and Kamarudin and Mat Noor (2024) demonstrate the iterative process of refining teaching practices to improve students' SPS through collaboration and inquiry-based digital learning. Additionally, Mat et al. (2025), conducted needs analyses to inform module development for teaching electrical topics in science, emphasizing teacher capacity-building and curriculum alignment. Collectively, these studies indicate that systematic and iterative methodologies, for example, Research and Development (R&D), ADDIE, and action research are particularly suitable for producing classroom-relevant and evidence-based instructional innovations.

The methodology of SPS research in Malaysian primary schools reveals a trend toward combining quantitative rigor with qualitative depth. Quantitative studies ensure measurement precision and generalizability, while qualitative and mixed-method designs provide contextual understanding and pedagogical insights. This methodological complementarity enhances the robustness of findings and supports the ongoing refinement of instructional approaches in science education (Mustafa et al., 2021; Ong et al., 2022; Ahmad & Iksan, 2021; Abu Bakar et al., 2021; Karupaiah & Daniel, 2021; Karim et al., 2024; Ariffin et.al., 2023).

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Analysis of Similarities in the Content

Across the reviewed studies, several thematic and content-related similarities emerge, particularly regarding the types of SPS emphasized and the contextual factors influencing their development. Table 3 shows summary of findings the content of SPS.

Table 3. Summary of findings regarding the content of SPS.

Type of Skill	Easy/Moderate Level	Difficult Level
Basic Science Process Skills	Observing, classifying, measuring, communicating	Predicting, making inferences
Integrated Science Process Skills	Interpreting data	Formulating hypotheses, conducting experiments

Most studies consistently highlight observing, classifying, measuring, and communicating as the most fundamental SPS for primary school pupils, while inferring, hypothesizing, and experimenting are identified as highly difficult to master (Mustafa et al., 2021; Ong et al., 2022; Karim et al., 2024). This pattern suggests that while students can readily engage in concrete, observable tasks, they often struggle with abstract reasoning and complex variable control. Furthermore, Ong et al. (2022) indicate that cultural, linguistic, and socioeconomic differences contribute to varying levels of SPS mastery, they found significant performance disparities between Malay and Orang Asli students.

Table 4. Summary of Pedagogical Approaches and Their Impact on Science Process Skills and Related Outcomes in Primary School Students

Pedagogical Approach	Key Outcomes	Effect Size / Significance	Notes
Inquiry-Based Science Education (IBSE)	Improved science process skills	Significant pre/post improvement ($p < 0.001$)	Shows strong impact on overall SPS mastery
Digital Science Games	Increased engagement and basic SPS	Moderate effect ($d = 0.78$)	Particularly effective for motivation and foundational skills
Peer Collaboration in School	Enhanced hypothesis formulation & variable control	Not quantified	Skills improved but still relatively weak; highlights need for guided practice
Heutagogy via Telegram	Gains in SPS and creative thinking	+21.5% SPS, +16.3% creative thinking (Wilcoxon $Z = –3.94$)	Demonstrates effectiveness of self-directed, technology-mediated learning

Moreover, based on summary of pedagogical approaches and their impact on SPS and related outcomes in primary school students (*see* table 4) Ahmad and Iksan (2021), Baharom et al. (2020), and Abdul Halim and Abdul Halim (2024) demonstrate that digital interventions, which range from educational games to mobile applications would enhance students' engagement, curiosity, and motivation in science learning. Similarly, Karupaiah and Daniel (2021) and Kamarudin and Mat Noor (2024) showed that inquiry-based and collaborative approaches could help students build a depth conceptual understanding through experimentation, peer interaction, and reflective dialogue. These studies converge on the view that active learning environments promote high SPS performance and the development of

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critical and creative thinking. Furthermore, qualitative studies reveal that teachers encountered pedagogical challenges in sustaining effective SPS learning. According to Abu Bakar et al. (2021), students often rely on peer collaboration to grasp complex SPS concepts, while teachers express the need for targeted training and instructional resources (Karupaiah & Saleh, 2025; Mat et al., 2025). These shared challenges underline the importance of continuous professional development and curriculum alignment to strengthen SPS instruction at the primary level. Besides, Arifin et al. (2024) and Engku Ismail and Matore (2024) emphasize inquiry-based learning (IBL) and argumentation-based strategies as effective in nurturing scientific reasoning and manipulative skills. Similarly, Yaakob et al. (2023) discussed that the inclusion of environmental and everyday-life contexts would promote science learning to be highly meaningful and connected to students' life experiences.

These studies showed that there was a strong alignment with inquiry-based, constructivist, and 21st-century learning paradigms, where science is taught as content knowledge, and a process of investigation and reasoning. The thematic convergence across studies from 2020 to 2025 highlights that Malaysian primary science education is moving toward more active, student-centred, and evidence-based teaching practices. The findings consistently strengthen the conclusion that SPS development is a cornerstone of quality science learning and should remain a priority in both research and practice (Ong et al., 2022; Ahmad & Iksan, 2021; Abu Bakar et al., 2021; Karupaiah & Daniel, 2021; Abdul Halim & Abdul Halim, 2024).

CONCLUSION

In conclusion, the development of SPS among Malaysian primary school students is strongly influenced using diverse methodologies, innovative pedagogical strategies, and contextual classroom factors. Quantitative approaches, particularly those employing Rasch Measurement Models and standardized SPS instruments, provide valuable evidence of students' mastery levels and skill progression, while qualitative and mixed-method designs offer rich insights into teaching practices and learning challenges. The integration of digital tools, inquiry-based learning, and collaborative pedagogies consistently enhances pupils' engagement, motivation, and critical thinking, demonstrating that active, student-centred approaches are most effective in cultivating SPS. However, persistent gaps remain, especially in higher-order skills including hypothesizing and experimenting, which require sustained teacher support and curriculum alignment. The findings underscore the need for continuous professional development, curriculum innovation, and evidence-based instructional design to strengthen science education in primary schools. Future research should expand cross-cultural comparisons and longitudinal analyses to better understand how SPS evolve across different learning contexts and educational levels.

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