



# Science process skills and scientific creativity in primary science education: The partial mediating role of classroom climate

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## ABSTRACT

Science process skills (SPS) and scientific creativity (SC) are widely recognized as central outcomes of contemporary science education, yet the mechanisms linking these constructs remain insufficiently understood. This study examines the partial mediating role of classroom climate in the relationship between students' SPS and SC. Grounded in social cognitive theory and the componential theory of creativity, the study employed a quantitative cross-sectional design using structural equation modelling with data from 350 eleven-year-old students in Malaysian public primary schools. Data were collected using validated instruments measuring SPS, perceived classroom climate, and SC. The findings indicate that SPS significantly predict SC both directly and indirectly through classroom climate. Classroom climate emerged as a significant partial mediator, indicating that a supportive, engaging, and autonomy-enhancing learning environment strengthens the translation of students' inquiry skills into creative scientific outcomes. These findings underscore the importance of pedagogical practices that simultaneously emphasize the development of SPS and the cultivation of positive classroom climates. The study contributes empirical evidence to the understanding of socio-cognitive mechanisms underlying SC and offers practical implications for curriculum design and teacher professional development aimed at promoting higher-order learning outcomes in primary science education.

**Keywords:** science process skills, scientific creativity, classroom climate, mediation, primary science education, structural equation modelling

## INTRODUCTION

Developing learners who can engage in inquiry and generating creative ideas is a central goal of contemporary science education (Waldrup & Prain, 2017). Science process skills (SPS) play a fundamental role in achieving this goal, as they enable students to observe, classify, measure, infer, predict, and experiment systematically (Idul & Caro, 2022). These skills are widely recognized as essential for meaningful engagement with scientific knowledge and for the development of higher-order thinking (Saïdo et al., 2018). Students who

demonstrate stronger SPS tend to show deeper conceptual understanding and greater ability to apply knowledge in novel situations (Melesse et al., 2025).

Scientific creativity (SC) has also gained increasing attention as an important outcome of science learning (Guler, 2025). SC refers to students' ability to generate original and appropriate ideas, explanations, or solutions within scientific contexts (Oh, 2022). Prior studies suggest that inquiry-oriented learning experiences can promote SC by encouraging exploration, divergent thinking, and idea construction (Yang et al., 2016a). However, research also indicates that not all students with strong inquiry skills necessarily demonstrate high levels of creativity, implying that additional contextual factors may influence this relationship (Yang et al., 2016b).

One contextual factor that may influence the development of SC is the classroom environment (Beghetto & Kaufman, 2014; Hong et al., 2022; Liu & Lin, 2014). Classroom climate, particularly in relation to teacher support, peer interaction, autonomy, and psychological safety, has been found to shape students' motivation, engagement, and willingness to take intellectual risks (Robinson, 2023). A positive classroom climate may therefore enhance the extent to which students' SPS are translated into creative scientific thinking and problem-solving (Runco, 2022). From a theoretical perspective, this relationship can be understood through social cognitive theory, which emphasizes the interaction between personal capabilities and environmental context, and the componential theory of creativity, which highlights the role of social environments in supporting creative performance (Rubenstein et al., 2018).

Although SPS, classroom climate, and SC have been widely studied as separate constructs, empirical studies examining their combined relationships remain limited, especially at the primary school level. Few studies have explicitly tested classroom climate as a mediating mechanism that explains how students' inquiry skills are translated into creative outcomes (Fan & Cai, 2022; Wang et al., 2023; Zhang et al., 2023). To address this gap, the present study investigates the mediating role of classroom climate in the relationship between SPS and SC among eleven-year-old students in Malaysian public primary schools.

## Problem Statement

One prominent area for improvement in primary science education is the development of students' SPS. Although these skills are widely recognized as fundamental to meaningful scientific inquiry, evidence suggests that many primary students demonstrate only moderate or low mastery of key skills such as observing, hypothesizing, interpreting data, and drawing conclusions (Choirunnisa et al., 2018; Ong et al., 2015). Insufficient development of these skills may limit students' ability to engage deeply with scientific tasks and reduce their capacity to construct meaningful understanding through inquiry-based learning (Jusoh et al., 2024). Without adequate SPS, students may struggle to participate effectively in higher-order scientific thinking (H. Sun et al., 2022).

Another important concern is the relatively low level of SC demonstrated by many students in school science contexts. Previous studies have reported that students often have trouble generating original ideas, proposing alternative explanations, or producing novel solutions to scientific problems (M. Sun et al., 2022). This limitation has been linked to instructional practices that emphasize correct answers and procedural completion rather than exploration and idea generation (Habib et al., 2024; Marrone et al., 2022). When students are not encouraged to think divergently or take intellectual risks, opportunities to develop SC may be constrained (Runco, 2022).

A further issue relates to the quality of the classroom environment in which science learning occurs. Research indicates that many classrooms remain teacher-centered, with limited opportunities for student autonomy, peer interaction, and open discussion (Al-Balushi et al., 2020; Lehesvuori et al., 2018). Such learning environments may discourage students from expressing ideas, asking questions, or experimenting with alternative approaches, all of which are essential for both inquiry and creativity (Karamustafaoglu & Pektaş, 2023; Richardson & Mishra, 2018). In contrast, a supportive classroom climate characterized by psychological safety and encouragement has been associated with greater student engagement and willingness to explore ideas (Reeve, 2013; Tas, 2016).

Although SPS, classroom climate, and SC have each been examined in prior studies, research investigating their interrelationships remains limited, particularly at the primary school level. Few empirical studies have

tested whether classroom climate functions as a mediating mechanism that explains how students' inquiry skills are translated into creative scientific outcomes (Fan & Cai, 2022; Wang et al., 2023). Addressing this gap is important for improving both theoretical understanding and practical approaches to fostering creativity in school science. Therefore, this study empirically examines whether classroom climate explains how students' SPS are translated into SC among eleven-year-old students in Malaysian public primary schools.

### Research objectives

This study aimed to examine the relationships among SPS, classroom climate, and SC, and to investigate the mediating role of classroom climate in the relationship between SPS and SC among eleven-year-old students in Malaysian public primary schools.

### Research questions

This study was guided by the following research questions:

1. What is the relationship between students' SPS and SC?
2. What is the relationship between students' SPS and classroom climate?
3. Does classroom climate mediate the relationship between SPS and SC among eleven-year-old students in Malaysian public primary schools?

### Research hypotheses

The following hypotheses were formulated to guide the study:

**Hypothesis 1:** There is a significant positive relationship between student's SPS and SC.

**Hypothesis 2:** There is a significant positive relationship between student's SPS and classroom climate.

**Hypothesis 3:** Classroom climate significantly mediates the positive relationship between SPS and SC among eleven-year-old students in Malaysian public primary schools.

### Science Process Skills

SPS are widely recognized as essential competencies in science learning, particularly at the primary school level (Choirunnisa et al., 2018; Harlen, 1999; Solé-Llussà et al., 2022). These skills include observing, classifying, measuring, predicting, inferring, hypothesizing, and experimenting, which enable students to engage meaningfully in scientific inquiry (Hartono et al., 2025). Through the application of these skills, students can construct understanding actively rather than passively receiving information (Özdeniz et al., 2023).

Empirical studies have shown that students with stronger SPS demonstrate higher levels of conceptual understanding and are more capable of applying scientific knowledge in novel situations (Tan et al., 2020). However, research has also reported that many primary students exhibit limited mastery of these skills, often due to instructional practices that prioritize content coverage over inquiry-based learning experiences (Wen et al., 2023). This limitation suggests a need for greater emphasis on developing SPS as a foundation for higher-order learning outcomes. Recent literature further suggests that SPS are closely related to broader cognitive outcomes, including critical thinking and creativity in science contexts (Amrulloh & Galushasti, 2022; Bhakti & Astuti, 2018). These findings indicate that SPS may play a key role in supporting students' creative engagement with scientific ideas.

### Science Process Skills and Classroom Climate

The relationship between students' cognitive abilities and the learning environment has received increasing attention in educational research (Bas, 2025; Kwan & Wong, 2015). Classroom climate, defined as students' perceptions of teacher support, peer interaction, autonomy, and emotional safety, has been shown to influence how students engage with learning tasks (Jang et al., 2025). Students who perceive their classroom environment as supportive and encouraging are more likely to participate actively and express their ideas confidently (Gasser et al., 2018).

Research suggests that students with stronger SPS may be more inclined to ask questions, share ideas, and engage in collaborative inquiry, particularly when the classroom climate supports autonomy and open communication (Sun et al., 2017; Zainuddin & Perera, 2019). In contrast, restrictive or highly evaluative

classroom environments may limit opportunities for students to apply their inquiry skills meaningfully. This suggests that classroom climate may shape how students' SPS are expressed in classroom practice. Empirical studies have also reported positive associations between inquiry-oriented teaching environments and students' engagement in science-related practices (Cairns & Areepattamannil, 2019). These findings provide support for examining the relationship between SPS and classroom climate within the present study.

### Classroom Climate and Scientific Creativity

SC refers to students' ability to generate original and appropriate ideas, explanations, or solutions within scientific contexts (Hu & Adey, 2002; Newton & Newton, 2009). Previous studies have indicated that creativity in science is not solely a function of individual ability but is strongly influenced by environmental factors, particularly the classroom context (Asda et al., 2025).

A positive classroom climate characterized by psychological safety, teacher encouragement, and opportunities for student voice has been found to support students' willingness to take intellectual risks and explore multiple ideas (Karpudewan & Meng, 2017; Tas, 2016). Such environments are especially important for creativity, as students are more likely to propose unconventional ideas when they feel their contributions are valued. Conversely, classrooms that emphasize correct answers and rigid procedures may inhibit students' creative expression (Terzidis & Borloz, 2026).

Several empirical studies have demonstrated significant associations between classroom climate and students' creative performance in academic contexts, including science learning (Hosseini, 2025; Wang et al., 2023). However, despite this growing evidence, limited research has examined how classroom climate may function as an explanatory mechanism linking students' inquiry-related skills to their SC, particularly among primary school learners (Gao et al., 2020). This gap further supports the need for the present study.

## METHODOLOGY

This study involved 350 eleven-year-old students from Malaysian public primary schools. The participants were selected using a proportionate stratified random sampling technique across five geographical zones in Malaysia which are Southern, Central, Northern, and Eastern Peninsular Malaysia, and East Malaysia. Eleven-year-old students were selected because they possess sufficient cognitive maturity and prior science learning experience to respond meaningfully to the research instruments (Piaget, 1964). The study adopted a quantitative research design, employing a survey method and structural equation modelling (SEM) for data analysis. The quantitative approach is appropriate for examining structural relationships among variables using numerical data. SEM was used to analyze the direct and indirect relationships between SPS, classroom climate, and SC within a single analytical model.

Three different instruments were used to collect data. SPS were measured using a multiple-choice test, which assessed students' understanding of key inquiry skills. Classroom climate was measured using a self-report questionnaire based on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), capturing students' perceptions of their learning environment. SC was assessed using open-ended test, in which students generated written responses to science-based prompts. These responses were evaluated using a scoring rubric to produce quantitative scores suitable for statistical analysis. All instruments were adapted from established measures and reviewed to ensure clarity and age-appropriateness for eleven-year-old students. The survey approach enabled efficient data collection from a large sample and supported the examination of relationships among the study variables using SEM.

### Research Instruments

The selection and adaptation of research instruments are critical to ensure that the measures accurately represent the constructs under investigation and are appropriate for the target population. In this study, all instruments were adapted from established measures of SPS, classroom climate, and SC to suit the linguistic, cultural, and educational context of Malaysian eleven-year-old students. The adaptation process aimed to enhance clarity, relevance, and age-appropriateness while preserving the original constructs and psychometric properties.

To establish content validity, the instruments were reviewed by a panel of ten experts, comprising science education experts, language experts, and educational measurement experts. The experts evaluated each item in terms of relevance, clarity of wording, cultural appropriateness, and alignment with the intended constructs. Their feedback was used to refine item wording, remove ambiguous statements, and improve the overall quality of the instruments. The involvement of experts from different fields strengthened the comprehensiveness and credibility of the content validation process (Beck, 2020).

In addition to expert review, construct validity was examined using confirmatory factor analysis (CFA). CFA was conducted to determine whether the observed items adequately represented the hypothesized latent constructs of SPS, classroom climate, and SC. This approach is consistent with established practices in quantitative educational research for evaluating instrument validity (Gallagher & Brown, 2013). Only items demonstrating acceptable factor loadings and model fit were retained for subsequent analysis. Overall, the combined use of expert validation and CFA provided strong evidence for the validity of the instruments and supported their suitability for measuring the study variables among primary school students.

### Science Process Skills

A 36-item multiple-choice test was developed to measure students' SPS. The test items were constructed based on the Malaysian year five science curriculum and assessment standard document (Ministry of Education Malaysia, 2019) and were organized into two dimensions: basic SPS and integrated SPS. The basic SPS assessed included observing, classifying, measuring and using numbers, making inferences, predicting, communicating, and using spatial and temporal relationships (Ministry of Education Malaysia, 2019). In contrast, the integrated SPS comprised interpreting data, defining operationally, controlling variables, formulating hypotheses, and experimenting (Ministry of Education Malaysia, 2019).

The results of factor analyses were utilized to evaluate the validity and reliability of this instrument. The factor loadings were obtained through CFA. The analysis showed that for basic SPS, the composite reliability (CR) was 0.85 and the average variance extracted (AVE) was 0.45, while for integrated SPS, CR was 0.91 and AVE was 0.66. Although the AVE value for basic skills was slightly below the recommended threshold of 0.50, the construct was retained because CR exceeded the acceptable level of 0.70, as suggested by Fornell and Larcker (1981) and Awang et al. (2023).

### Classroom Climate

A 16-item questionnaire was adapted and modified from the classroom climate instrument for students developed by López et al. (2018) to measure students' perceptions of classroom climate in Malaysian primary science classrooms. The instrument was modified by rewording selected items, reducing the number of items, and contextualizing the content to ensure age appropriateness and relevance for eleven-year-old Malaysian primary school pupils while retaining the original four-dimensional structure. The four dimensions comprised physical environment, teacher–student interaction, peer relationships, and teacher learning orientation. All items were rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

The construct validity and reliability of the instrument were evaluated using CFA. The physical environment dimension demonstrated a CR of .81 and an AVE of .51, teacher–student interaction yielded CR = .77 and AVE = .46, peer relationships produced CR = .84 and AVE = .57, and teacher learning orientation demonstrated CR = .87 and AVE = .63. Overall, all CR values exceeded the recommended threshold of .70, indicating satisfactory internal consistency. Although the AVE for the teacher–student interaction dimension (.46) was slightly below the recommended threshold of .50, the construct was retained because its CR exceeded .70, indicating acceptable convergent validity when considered alongside the CR values (Awang et al., 2023; Fornell & Larcker, 1981).

### Scientific Creativity

Students' SC was measured using four open-ended structured test adapted from the SC test for fifth graders developed by Siew et al. (2014), which was originally based on the SC test proposed by Hu and Adey (2002). The items assessed three dimensions of SC: trait, process, and product. Students' responses were scored using a structured scoring rubric. The results of factor analyses were utilized to evaluate the validity and reliability of this instrument. CFA showed that factor loadings ranged between 0.84 and 0.87, with CR =

**Table 1.** Standardized path coefficients for the direct and mediating structural models

Variables		$\beta$	p
Direct model	SPS $\rightarrow$ SC	0.65	0.001
	SPS $\rightarrow$ Classroom climate	0.81	0.001
Mediating model	Classroom climate $\rightarrow$ SC	0.41	0.001
	SPS $\rightarrow$ SC	0.35	0.001

0.89 and AVE = 0.73. Therefore, the AVE and CR values exceeded the acceptable levels of 0.50 and 0.70, respectively, as suggested by Awang et al. (2023), indicating that the SC construct achieved satisfactory convergent validity and reliability.

## FINDINGS AND DISCUSSION

The present study provides empirical evidence that SPS play a substantial role in fostering SC among primary school students. The structural model demonstrated a strong and statistically significant direct effect of SPS on SC ( $\beta = 0.65$ ,  $p < 0.001$ ), explaining 53% of the variance in students' creative performance in science learning (Table 1). This relatively high coefficient of determination indicates that SPS constitute a major explanatory factor in understanding how SC develops at the primary school level.

From a theoretical perspective, this finding is consistent with social cognitive theory (Bandura, 1986), which posits that learning occurs through the reciprocal interaction of personal factors, behavior, and environmental influences. SPS represent students' behavioral capabilities that enable them to actively engage in scientific inquiry, thereby enhancing their confidence and competence in generating creative scientific ideas. Students who demonstrate higher proficiency in observing, classifying, measuring, predicting, inferring, and experimenting are therefore more likely to exhibit greater SC because these inquiry behaviors provide opportunities for exploration, experimentation, and creative problem solving.

When classroom climate was introduced as a mediating variable, the direct effect of SPS on SC remained significant but was reduced in magnitude ( $\beta = 0.35$ ,  $p < 0.001$ ). This reduction indicates partial mediation, suggesting that classroom climate explains part of the mechanism through which SPS influence SC. The strong path from SPS to classroom climate ( $\beta = 0.81$ ,  $p < 0.001$ ) further implies that students' active engagement in inquiry-based practices contributes to the development of a more positive and supportive classroom environment. Classrooms characterized by frequent hands-on investigations, questioning, and collaborative problem-solving are likely to promote mutual respect, meaningful interactions, and intellectual openness.

The significant relationship between classroom climate and SC ( $\beta = .41$ ,  $p < .001$ ) can likewise be interpreted through social cognitive theory. According to Bandura (1986), environmental factors interact with learners' cognitive and behavioral characteristics to shape learning outcomes. A supportive classroom climate characterized by positive teacher-student interactions, collaborative peer relationships, and opportunities for autonomous inquiry provides an environment that encourages students to apply their SPS creatively. Such learning environments strengthen students' willingness to explore ideas, take intellectual risks, and develop original scientific solutions. These findings suggest that classroom climate functions as an enabling environmental factor that facilitates the development of SC by supporting the effective application of students' SPS.

The mediating role of classroom climate also aligns with Amabile's (1983) componential theory of creativity, which emphasizes the interaction between domain-relevant skills, creativity-relevant processes, and the social environment. In this study, SPS represent domain-relevant skills, while classroom climate functions as a social-environmental catalyst that enables these skills to be translated into creative scientific outcomes. Even when students possess strong inquiry skills, their creative potential may not be fully realized unless the classroom environment supports autonomy, exploration, and idea sharing. Hence, classroom climate serves as a critical pathway that amplifies the impact of SPS on SC.

The model fit indices further confirm the robustness of the proposed mediation model ( $\chi^2/df = 2.058$ ; CFI = 0.923; TLI = 0.916; RMSEA = 0.055), indicating that the hypothesized relationships among SPS, classroom climate, and SC are theoretically and empirically sound (Figure 1 and Figure 2). These findings extend prior research by demonstrating not only a direct relationship between inquiry skills and creativity but also explaining how and why this relationship operates within the classroom context.

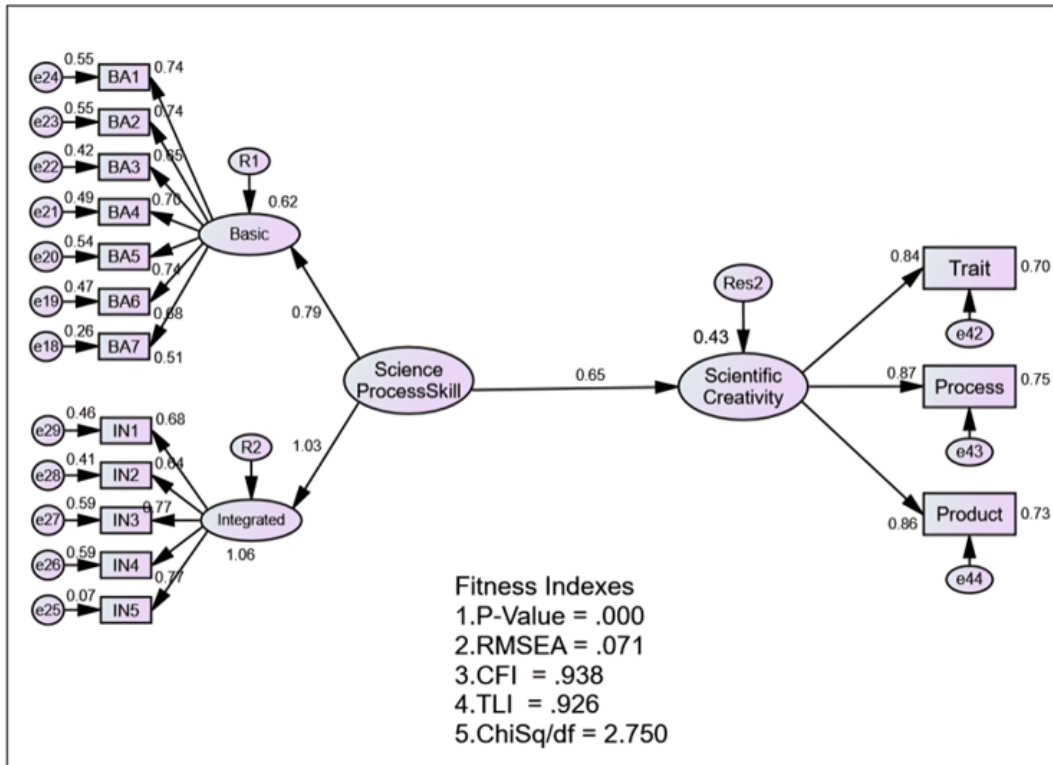


Figure 1. The direct effect of SPS towards SC (the authors' own work)

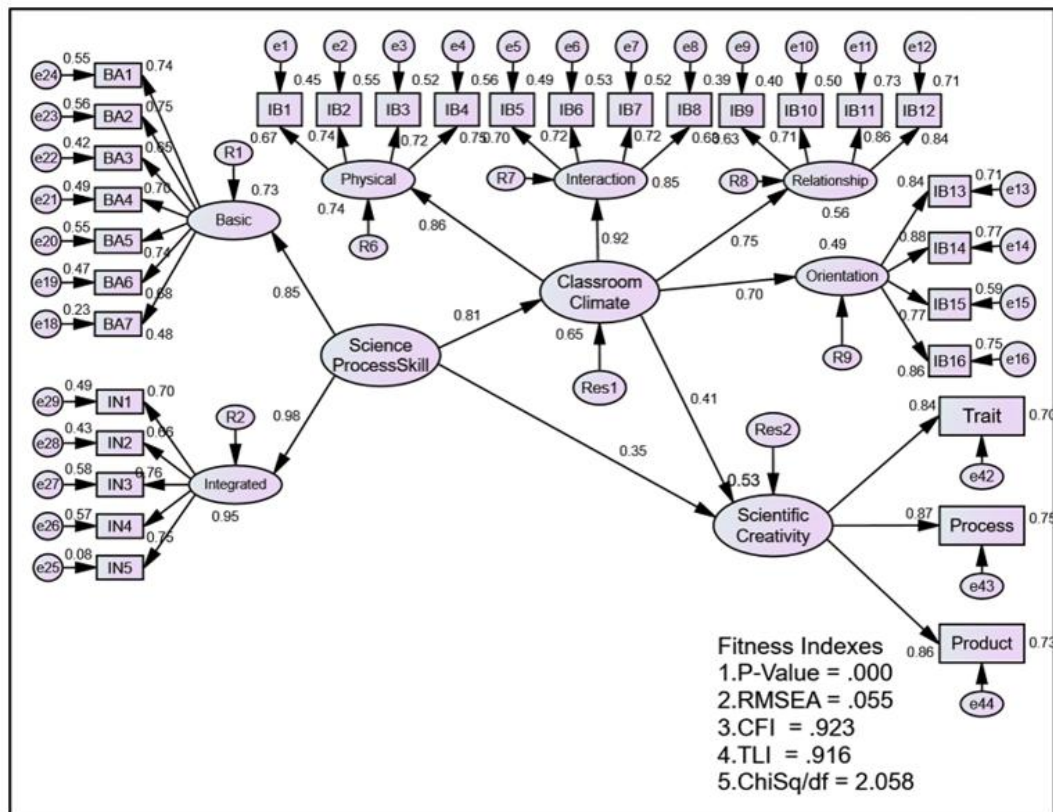


Figure 2. Analysis of the mediation model (the authors' own work)

Overall, the findings suggest that efforts to enhance SC among primary school students should not focus solely on developing SPS in isolation. Instead, instructional approaches should simultaneously cultivate a positive classroom climate that supports inquiry, collaboration, and open expression of ideas.

Inquiry-oriented pedagogy, formative feedback, and supportive teacher-student interactions collectively strengthen SPS while creating the environmental conditions necessary for creativity to flourish. This integrated approach provides a more holistic and theoretically grounded explanation of how SC can be effectively nurtured in primary science education.

### Implication of Research

This study has important implications for science education by demonstrating that SPS contribute to SC both directly and indirectly through a positive classroom climate. For Malaysian primary schools, these findings provide empirical support for strengthening instructional practices that develop students' SPS while fostering supportive classroom climates characterized by positive teacher-student interactions, collaborative peer relationships, student autonomy, and opportunities for idea sharing. The findings also have important implications for teacher professional development, curriculum design, and educational policy by emphasizing instructional practices that simultaneously strengthen students' SPS and cultivate classroom environments that promote SC.

## CONCLUSIONS

This study demonstrated that SPS contribute significantly to SC both directly and indirectly through classroom climate among eleven-year-old students in Malaysian public primary schools. The findings indicate that strengthening students' SPS while fostering supportive classroom environments characterized by positive teacher-student interactions, collaborative peer relationships, student autonomy, and opportunities for idea sharing can effectively enhance SC. These findings provide empirical support for social cognitive theory and the componential theory of creativity by demonstrating that SC develops through the interaction between students' cognitive capabilities and supportive learning environments. Although this study was limited to eleven-year-old students from selected Malaysian public primary schools, future research should include more diverse samples across different school types, geographical regions, and socio-cultural contexts to enhance the generalizability of the findings. Overall, the proposed mediation model contributes to a deeper understanding of how SPS and classroom climate jointly influence SC and offers practical implications for teacher professional development, curriculum design, and classroom practices in primary science education.

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**AI statement:** During the preparation of this work, the authors used ChatGPT to improve language clarity and readability. Following the use of this tool, the authors critically reviewed and edited the content as necessary and took full responsibility for the integrity and accuracy of the final manuscript.

**Declaration of interest:** The authors declared no competing interest.

**Data availability:** Data generated or analyzed during this study are available from the authors on request.

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