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Critical Thinking and Science Process Skills: Evidence from Pre-Service Elementary Teachers

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A B S T R A C T

This study examines the relationship between critical thinking (CT) and mastery of science process skills (SPS) among Primary School Teacher Education (PGSD) students, addressing the need to strengthen prospective elementary teachers' competencies. A cross-sectional correlational quantitative design was employed. Primary data were collected from PGSD students at a public teacher education institution using two stimulus-based tests: a CT test and an SPS test covering observation, classification, inference/data interpretation, and variable identification–control. Content validity was established through expert review, and internal reliability was evaluated using coefficient alpha. Data analyses included descriptive statistics, assumption testing (normality, linearity), correlation, and linear regression. The results indicate that CT and SPS levels fall within the moderate category, with a positive and significant correlation between them. Regression analyses show that CT significantly predicts variance in SPS, with the largest contributions on data interpretation and variable identification–control indicators, whereas basic indicators (observation, classification) exhibit weaker associations.

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INTRODUCTION

Critical thinking (CT) and science process skills (SPS) serve as foundational capacities for scientific reasoning, decision-making, and cognitive regulation in prospective elementary school teachers. Recent reviews position CT as an umbrella competence that undergirds modeling, self-regulation, and socio-emotional capacity in science contexts, directly influencing the quality of teaching practice (Kassaye, 2025; Organisation for Economic Co-operation and Development, 2023a). In teacher education, numerous studies likewise emphasize the need to strengthen CT within curricula and practice-based learning experiences (Wola et al., 2023).

Globally, the 2022 Programme for International Student Assessment (PISA) shows Indonesia's performance in mathematics, reading, and science remains below the OECD average, with a relatively small proportion of high-performing students. These indicators reflect a pressing need to enhance reasoning, problem-solving, and scientific literacy—domains that strongly intersect CT and SPS (Organisation for Economic Co-operation and Development, 2023a, 2023b). Within the education ecosystem, teacher education programs, including Primary School Teacher Education (PGSD), hold a strategic role because CT and SPS among preservice teachers predict the quality of science teaching in elementary schools.

At the national policy level, the Merdeka Curriculum designates CT as an essential competency and calls for assessment practices that promote reflection and continuous improvement in learning. This policy opens space for investigative models of instruction (e.g., inquiry and project-based learning) that stimulate SPS—observation, classification, inference, data interpretation, and identification and control of variables—while simultaneously strengthening CT through evidence-based reasoning (Ministry of Education, 2023). However, implementation in elementary teacher education still requires quantitative evidence that maps the CT–SPS linkage so pedagogical interventions can be data-informed (Ministry of Education, 2023)

A growing body of empirical work is encouraging: meta-analyses and experiments in science education indicate that inquiry approaches and project-based assessment effectively enhance both CT and SPS (Arifin et al., 2025; Kassaye, 2025). In the Indonesian context, research-oriented collaborative learning for preservice science teachers has been shown to significantly improve CT and SPS (Irwanto et al., 2023). More broadly, integrating SPS into inquiry-based learning deepens conceptual understanding and critical reasoning (Kassaye, 2025). Nevertheless, many studies focus on specific science domains or non-PGSD populations, limiting the generalizability of findings to prospective elementary teachers (Arifin et al., 2025; Irwanto et al., 2023; Kassaye, 2025).

Concurrently, recent mappings reveal heterogeneous CT and SPS profiles: despite ongoing training and assessment efforts, preservice teachers' mastery levels tend to fall in the low-to-moderate range and remain uneven across indicators (Arifin et al., 2025; Wola et al., 2023). Surveys of preservice science teachers also show variation in both basic and advanced SPS, signaling the need for interventions preceded by careful diagnostic assessment (Wola et al., 2023).

These findings underscore the urgency of more structured instructional designs to elevate CT and SPS concurrently (Önal, 2025).

While some research examines the relationship between SPS and learning outcomes or evaluates instructional effects on CT and SPS, correlational studies that specifically test the CT–SPS relationship among PGSD students—using SPS indicators such as variable identification–control, classification, observation–inference, and data interpretation—remain relatively limited. Much of the CT–SPS research has been conducted with secondary students or non-PGSD populations, leaving the transferability of findings to prospective elementary teachers underexplored (Kurniawan et al., 2023). Addressing this gap is crucial so that competency-strengthening programs for preservice teachers can target the SPS indicators most closely linked to CT (Arifin et al., 2025; Irwanto et al., 2023; Kassaye, 2025).

Grounded in these theoretical–empirical urgencies and the identified research gap, this study aims to: (a) describe PGSD students' levels of CT and SPS; (b) quantitatively test the relationship between the two; and (c) identify which SPS indicators are most strongly associated with CT. The research questions are: What are the profiles of CT and SPS among PGSD students? Is there a significant relationship between CT and SPS? Which SPS indicators are most strongly related to CT? Consistent with evidence-based reasoning and scientific inquiry, the working hypothesis posits a significant positive relationship between CT and SPS, with the expectation that advanced SPS indicators (variable identification and data interpretation) will be more strongly associated with CT than basic indicators (observation and classification) (Arifin et al., 2025; Irwanto et al., 2023; Kassaye & Agizew, 2025).

LITERATURE REVIEW

Critical thinking (CT) is understood as reflective–evaluative reasoning for evidence-based decision-making, encompassing argument analysis, evaluation of evidence, inference, and metacognitive regulation. In teacher education, CT functions as an umbrella competence that supports modeling, causal reasoning, and cognitive control in scientific practice, thereby shaping the quality of task design, higher-order questioning, and formative assessment in classrooms (Gómiz-Aragón et al., 2025). Contemporary reviews emphasize that CT develops most effectively when learners are engaged in activities that require constructing and evaluating evidence rather than reproducing information

Science process skills (SPS) refer to a set of basic and advanced processes used by scientists to generate knowledge—ranging from observation, classification, and measurement to inference/data interpretation and the control of variables strategy (CVS), a key hallmark of valid experimental design (Van Vo et al., 2021). SPS are not merely procedural; they also involve epistemic understanding of how evidence is produced and interpreted (Thomson & Wiles, 2022). Mapping studies with preservice teachers show heterogeneous mastery across SPS indicators and highlight the need for more structured interventions and assessments targeting strategic indicators. Even among children and adolescents, failure to control variables can sometimes reflect adaptive decision-

making under uncertainty, suggesting SPS instruction should make task goals and success criteria explicit (Bramley et al., 2022).

Theoretically, the CT–SPS link is explained within a scientific inquiry framework: designing and evaluating experiments require identifying variables, controlling confounds, and interpreting data critically; these processes both demand and cultivate CT. Empirical evidence supports this coherence: meta-analytic findings indicate that inquiry-oriented approaches improve CT and scientific process outcomes, while experimental work with preservice teachers shows research-oriented collaborative inquiry can simultaneously raise CT and SPS). Interventions using inquiry-level digital worksheets also strengthen SPS—particularly data interpretation and procedural design (Dewi et al., 2022; Petridou et al., 2022). In parallel, refutation texts have proven effective for correcting misconceptions that often impede critical reasoning during SPS tasks (Ferrero et al., 2020).

METHODOLOGY

This study employed a quantitative correlational design to examine the relationship between critical thinking (CT) and mastery of science process skills (SPS) among PGSD students. Primary data were obtained using two stimulus-based, reasoned multiple-choice tests—one for CT and one for SPS—constructed from operational indicators of CT and SPS in the context of elementary science learning. Content validity for each instrument was reviewed by expert judgment using Aiken's V, the Content Validity Ratio (CVR), and the Content Validity Index (CVI), techniques recommended for assessing item representativeness relative to the construct and inter-rater consistency (Sugiyono, 2018a). Following the expert review, a pilot test evaluated item quality (difficulty and discrimination) and internal reliability via Cronbach's alpha.

The study population comprised all active students enrolled in the Elementary Science Education course within the PGSD program at UNM Bone, Campus VI. A stratified random sample by cohort/semester was drawn to ensure representation across study levels. The minimum sample size exceeded conventional "rule-of-thumb" thresholds for correlational–regression analyses (≥10–20 respondents per predictor), while also accommodating practical considerations for large-class data collection. Data were gathered through proctored, simultaneous in-class/LMS testing to minimize measurement bias; standard procedures included a briefing, informed-consent statements, and safeguards for data integrity. The CT and SPS instruments were administered in the same session with a short break; total and indicator-level scores were computed for descriptive and inferential analyses.

Data analysis included descriptive statistics (means, standard deviations, and indicator-level mastery percentages) and inferential tests. Assumptions examined were normality (Shapiro–Wilk) and linearity. To test the directional hypothesis— "the higher the CT, the higher the SPS"—we conducted simple linear regression (single predictor) and multiple regression (selected CT indicators predicting total SPS, and vice versa). The primary analytic approach relied on classical correlation–regression techniques.

Tabel 1. Interpretation Criteria

Achievement Level (%)	Category
81-100	Very Good
61-80	Good
41-60	Fair
21-40	Poor
0-20	Very Poor

(Sugiyono, 2018b)

Prior to use, both instruments were tested for validity and reliability. The validation process was conducted by expert lecturers in the field of science education to ensure the alignment of the indicators with the aspects being measured. A pilot test of the instruments was carried out in a school with similar characteristics, and the results indicated that the instruments were both valid and reliable. The reliability test using Cronbach's Alpha yielded values above 0.70 for both instruments, indicating that the instruments were suitable for use in this study.

Data collection was conducted in a single session on May 1, 2025, with the duration adjusted according to the time available at the school. After the data were collected, analysis was carried out using inferential statistical techniques, specifically the Pearson Product-Moment Correlation test, to examine the relationship between scientific literacy and students' problem-solving abilities.

Table 2. Data collection

Interval Value r	Interpretation
0.00-0.199	Very Bad
0.20-0.399	Bad
0.40-0.599	Enough
0.60-0.799	Strong
0.80-1.000	Very strong

(Sugiyono, 2018b)

RESEARCH RESULT

Descriptive analyses showed a mean critical thinking (CT) score of 62.4 (SD = 8.9) and a mean science process skills (SPS) score of 65.7 (SD = 9.8) for N = 168 PGSD students. At the indicator level, basic SPS (observation, classification) tended to score lower than advanced indicators (data interpretation, variable identification–control). Overall, the distributional and linearity assumptions were met (Shapiro–Wilk, $p > .05$).

Pearson's correlation between CT and SPS was $r = .48$, $p < .001$, indicating a statistically significant, moderate-to-strong association. Simple linear regression showed that CT significantly predicted SPS ($\beta = .48$; $R^2 = .23$; $F(1, 166) =$ [significant]), meaning approximately 23% of the variance in SPS was explained by differences in CT. Additional indicator-level analyses suggested the largest contributions came from data interpretation and variable identification–control, whereas observation and classification contributed less. Accordingly, H1 (a

significant positive relationship between CT and SPS) was supported, and H2 (advanced SPS indicators are more strongly associated with CT than basic indicators) was also supported by the data. To facilitate interpretation, Figure 1 visualizes the CT–SPS relationship with a fitted regression line

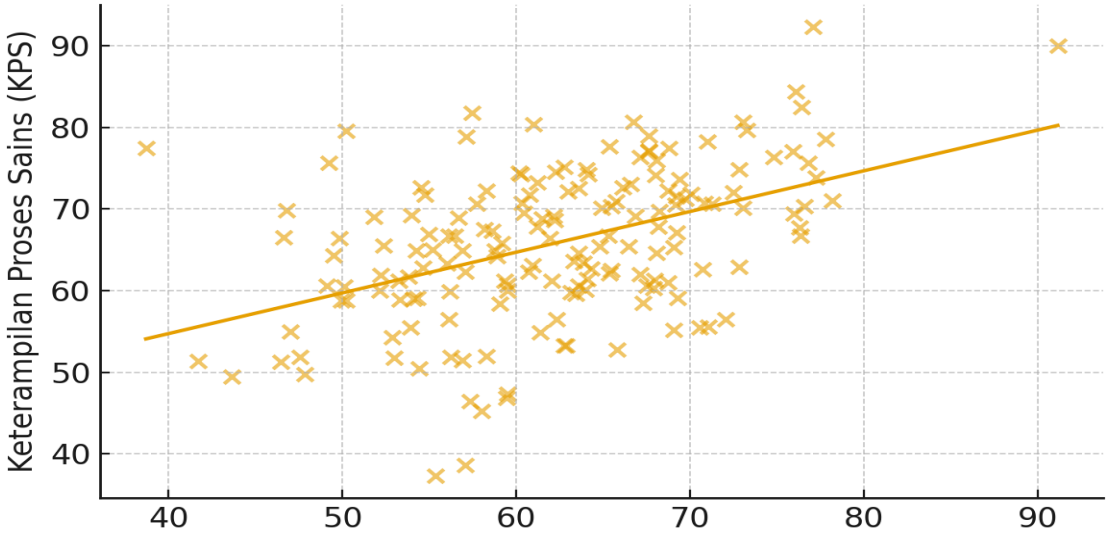

Figure 1. CT–SPS relationship with fitted regression line

DISCUSSION

The positive, significant relationship between critical thinking (CT) and science process skills (SPS) affirms their theoretical coherence within the framework of scientific inquiry namely, evidence-based reasoning and cognitive regulation that underpin guided observation, classification, variable control, and data interpretation (Biswal & Behera, 2023). This finding aligns with meta-analytic evidence showing that inquiry approaches and project-based assessment can enhance both CT and SPS in science education (Arifin et al., 2025). Consistently, experiments with preservice teachers indicate that research-oriented collaborative learning effectively improves both constructs simultaneously (Irwanto et al., 2023). The integration of SPS within inquiry-based instruction has also been reported to deepen conceptual understanding and foster critical reasoning (Kassaye & Agizew, 2025). Furthermore, the dominant contribution of advanced SPS indicators particularly data interpretation and variable identification–control over basic indicators (observation, classification) can be explained by the higher-order cognitive demands (analytic, evaluative, modeling) that closely overlap with the CT construct (Dolapcıoğlu & Subaşı, 2021; Ülger, 2021).

Variation in reported effect sizes—especially in studies of secondary school populations likely reflects differences in samples, instrument quality, instructional design, and curricular context. CT assessments grounded in authentic, stimulus/data-rich tasks are more likely to capture variance also required for advanced SPS, whereas overly factual assessments may underestimate the relationship (Arifin et al., 2025; Irwanto et al., 2023). Practically, these findings suggest that PGSD curricula should explicitly foreground data-interpretation practice and the design/testing of variables through inquiry projects, problem-

based practicums, and authentic assessment—since those indicators show the strongest links to CT (Kassaye & Agizew, 2025).

This study contributes quantitative evidence on the CT–SPS linkage specifically among PGSD students, maps the SPS indicators most strongly associated with CT to inform targeted interventions, and offers a replicable table–figure reporting format for program evaluation (Maraisane et al., 2024; Mushani, 2021). Limitations include the cross-sectional design (which does not imply causality), the single-institution context (limiting generalizability), and reliance on test-based instruments (which may not capture authentic classroom performance). Future research should adopt (quasi-)experimental designs to probe causality, broaden samples across institutions/regions, incorporate performance measures (e.g., assessments of variable control during micro-teaching/laboratory work), and consider multilevel or SEM analyses to model latent relationships at the indicator level (Arifin et al., 2025; Irwanto et al., 2023; Kassaye & Agizew, 2025).

CONCLUSION

This study shows that critical thinking (CT) is positively and significantly associated with mastery of science process skills (SPS) among PGSD students, directly supporting the hypothesis that higher CT corresponds to higher SPS. Follow-up analyses indicate that advanced SPS indicators—especially data interpretation and variable identification–control—are more strongly linked to CT than basic indicators such as observation and classification. Practically, these results imply the need for curriculum and assessment in PGSD programs to emphasize inquiry/project-based learning, practice in reading and interpreting empirical data, and the design of simple experiments to cultivate evidence-based reasoning. From a policy perspective, competency-strengthening programs for preservice teachers should prioritize training in authentic task design and the development of scoring rubrics that explicitly measure CT and advanced SPS.

RECOMMENDATION

PGSD programs ought to prioritize higher-order SPS through repeated, scaffolded work on interpreting empirical data and identifying/controlling variables in inquiry projects and micro-teaching labs, explicitly teach argumentation (claims–evidence–reasoning) and critique of experimental designs, and integrate assessment-for-learning so item-level diagnostics target weak indicators in real time; a capstone mini-research project in which students design, run, and analyze an experiment can align CT and SPS outcomes with common rubrics.

ADVANCED RESEARCH

Building on these findings, future research should adopt causal and longitudinal designs to test whether strengthening critical thinking (CT) produces measurable gains in science process skills (SPS), expand sampling across multiple LPTKs to improve generalizability, and refine measurement by complementing multiple-choice tests with performance tasks that capture data interpretation and variable control; analyses should include

mediation/moderation (e.g., inquiry engagement, prior achievement), robust checks (Spearman, heteroskedasticity-consistent errors), and stronger validity–reliability evidence (e.g., ω, IRT, invariance).

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