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Effectiveness of the Project–Combine–Eliminate Learning Model in Improving Elementary Students' Science Process Skills

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(Received: 18 Aug 2026; Accepted: 14 Sept 2026; Published: 16 Oct 2026)

Abstract

This study aimed to develop and evaluate the effectiveness of the Project-Combine-Eliminate (PCE) learning model in enhancing primary school students' science process skills. Science process skills are essential competencies that equip students to respond effectively to the demands of 21st-century education. The study employed a quantitative research and development (RD) design involving 194 primary school students in Probolinggo, Indonesia. The development procedure comprised needs analysis, instructional design, expert validation, limited and extensive trials, and effectiveness testing. Researchers systematically developed and refined the PCE learning model through expert appraisal, implementation trials, and empirical evaluation. The validation results demonstrated that the PCE model possessed high levels of construct and content validity. Furthermore, the practicality assessment indicated that the model could be implemented effectively, as reflected by a mean implementation score of 3.68 and high reliability coefficients. The effectiveness analysis further demonstrated substantial improvements in students' science process skills, as evidenced by higher post-test scores and moderate-to-high N-Gain categories. Overall, the findings suggest that the PCE learning model represents a promising innovative instructional approach for supporting science learning and strengthening students' scientific competencies in primary education.

Keywords: Elementary Students; PCE Learning Model; Science Process Skills.

1. Introduction

Science Process Skills (SPS) encompass a range of scientific competencies that enable learners to investigate phenomena, collect and interpret evidence, and communicate scientifically grounded explanations. SPS are generally categorized into basic skills, including observation, measurement, classification, inference, and communication, and integrated skills, such as identifying variables, formulating hypotheses, designing investigations, interpreting data, and constructing explanations ([1]; [2]). For fourth-grade primary school students, the present study focuses on observation, measure-

ment, classification, inference, conclusion, and communication, as these competencies are developmentally appropriate and can be directly demonstrated through concrete and meaningful scientific activities. These indicators provide a coherent foundation for fostering students' scientific reasoning and enabling them to formulate and communicate evidence-based conclusions ([3]; [4]).

A preliminary survey conducted between March and April 2025 across several primary schools in Probolinggo, Indonesia, identified inadequate student performance among fourth-grade students on the topic of matter and its changes. Classroom observations indicated that students experienced difficulties in conducting systematic observations, performing quantitative measurements, and verbally articulating observed phenomena. The results of the pre-experimental assessment showed that only 56.5% of students in Grade IV-A and 50% of students in Grade IV-B demonstrated adequate comprehension of the learning material. The findings further indicated that measurement constituted the weakest SPS domain, with both groups obtaining comparatively low mean scores. The identified problem can therefore be characterized as insufficient development of SPS across the indicators of observation, measurement, classification, inference, conclusion, and communication, particularly in relation to learning about changes in the state of matter. Among these indicators, measurement represented the most critical area of difficulty, as it yielded the lowest score. Addressing this deficiency is important because limited development of SPS may constrain students' capacity to engage in meaningful scientific inquiry and, consequently, reduce the effectiveness of science instruction in primary education. Accordingly, this study seeks to address these learning difficulties by developing an instructional approach that can systematically strengthen students' SPS across the identified indicators.

An alternative is to develop a learning syntax that systematically connects project inquiry with creative modification to strengthen SPS. Although PjBL supports observation, experimentation, data interpretation, and conclusion formation, its open-ended structure may not explicitly guide students to refine project procedures or critically remove ineffective elements ([5]; [6]). SCAMPER, meanwhile, provides structured prompts for creative transformation, but it is not inherently organized around sustained scientific investigation ([7]). Therefore, PCE integrates project-based inquiry with Combine and Eliminate as pedagogically sequenced processes: students collaboratively integrate ideas or procedures and eliminate irrelevant or ineffective elements before concluding. This integration distinguishes PCE from conventional PjBL and direct SCAMPER implementation.

However, the PjBL learning approach has specific challenges. Deficiencies in the execution of the PjBL learning model in primary schools encompass inadequate time management, instructors' limited understanding of the core principles of the PjBL learning model, maintaining student engagement, managing group dynamics, and accurately assessing individual contributions ([8]). This requires terminology that can augment the PjBL model syntax to establish criteria for measurement in SPS. The syntax of the Scamper method (Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, Reverse) can enhance the PjBL model syntax, as Scamper provides a creative and user-friendly approach to improving project-based learning. The application of the PjBL model utilizing the Scamper technique at the university level remains unexplored at the primary school level ([9]; [10]).

Research on PjBL model trends from 2016 to 2023 reveals that the utilization of the research and development strategy was only 5.88% ([11]). The results of Scamper bibliometric studies are inadequately explored throughout the scholarly community ([12]). This research's originality lies in distinguishing between the project model and combinatory syntax, which have not been simultaneously employed in primary school science education. This strategy offers an innovative amalgamation of project-based learning experiences with strategies aimed at improving SPS. The purpose of this study is to establish a pragmatic and effective project-combine-eliminate learning paradigm designed to improve SPS in primary schools.

Previous studies have predominantly examined the implementation of Project-Based Learning (PjBL) as an instructional approach for enhancing students' learning engagement and conceptual understanding. However, relatively limited research has integrated the SCAMPER strategy into the syntax of project-based learning, particularly for the systematic development of science process skills (SPS) in primary education. Moreover, existing studies have rarely investigated the effectiveness of integrating project formulation, collaborative combination, and elimination phases within a unified instructional framework to simultaneously develop students' abilities in observation, measurement, classification, inference, conclusion, and communication. This gap highlights the need for an instructional model that not only incorporates the experiential and collaborative characteristics of project-based learning but also systematically facilitates the generation, integration, refinement, and elimination of ideas during scientific inquiry. To address this gap, the present study proposes the Project-Combine-Eliminate (PCE) learning model as an innovative instructional framework for primary science education. The novelty of the PCE model lies in its systematic integration of project-based learning syntax with the Combine and Eliminate phases adapted from the SCAMPER strategy, thereby providing a structured pedagogical mechanism for strengthening students' science process skills through project-oriented scientific activities.

2. Methods

This study employed a research and development (R&D) design to develop a valid, practical, and effective Project-Combine-Eliminate (PCE) learning model aimed at enhancing students' Science Process Skills (SPS) in primary education. The development procedure was adapted from the systematic instructional design framework proposed by [13], which emphasizes an iterative process of analysis, design, development, formative evaluation, and revision. This framework was adapted to ensure that the model-development process was appropriately aligned with the specific objectives, pedagogical requirements, and contextual characteristics of science education at the primary school level. Through this systematic and iterative procedure, the PCE model was progressively refined based on expert evaluation, implementation feedback, and empirical evidence to establish its validity, practicality, and effectiveness ([13]). Accordingly, seven stages were operationalized: (1) preliminary model development, (2) expert validation, (3) small-scale trial, (4) feasibility trial, (5) extensive trial, (6) effectiveness evaluation, and (7) final product revision. Each stage informed subsequent refinement through iterative evaluation.

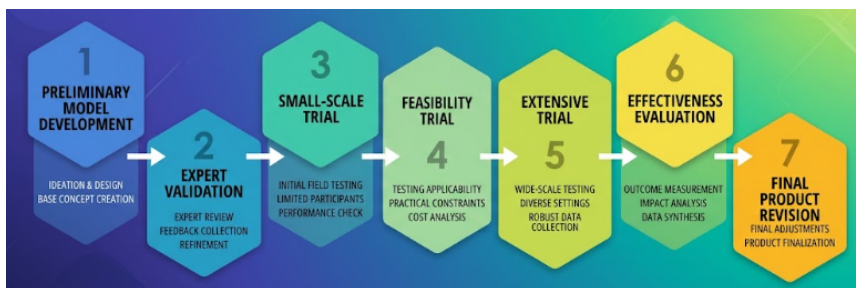


Figure 1. Design Framework of Dick and Carey

The participants were 194 fourth-grade children, distributed across one limited trial and three extensive trials. The limited trial at SD Pabean involved Class A ($n = 26$) and Class B ($n = 24$). The extensive trials were conducted at SDN Sumberwetan 2 with Class A ($n = 23$) and Class B ($n = 21$), SDN Mayangan 4 with Class A ($n = 26$) and Class B ($n = 28$), and SDN Sumbertaman 2 with Class A ($n = 24$) and Class B ($n = 22$). Thus, the study included 194 unique participants. The same participants completed

the pre-test and post-test; therefore, these repeated measurements were not counted as additional participants. The schools were purposively selected to represent different academic-performance contexts and learning environments.

The validation standards constitute one technique for data collection, alongside the student SPS examinations and the regulations governing their utilization. The content validation criteria for the learning model encompass (1) requirements assessment, (2) relevance, (3) the framework for model development, (4) a description of the learning model, and (5) linguistic usage. The construct validation of the learning model encompasses (1) coherence in the model's design, (2) alignment between theoretical and empirical support in the model's evolution, and (3) characteristics of the learning model's description. The model's pragmatic suggestions encompass an observation sheet for each stage of the learning model's execution and an observation sheet for learning challenges. The SPS test is organized as an evaluation consisting of the following components: (1) observation, (2) measurement, (3) categorization, (4) inference, (5) conclusion, and (6) communication ([sokolowski2015scientific]). Table 1 demonstrates the validity of the SPS test instruments, whereas Table 2 indicates their reliability.

Table 1. Results of the SPS test validity

Pretest				Posttest			
Item	Provisions	Nilai Sig.	Description	Item	Provisions	Nilai Sig.	Description
P1	Sig. < 0.05	0.002	Valid	Q1	Sig. < 0.05	< 0.001	Valid
P2	Sig. < 0.05	0.011	Valid	Q2	Sig. < 0.05	0.003	Valid
P3	Sig. < 0.05	0.019	Valid	Q3	Sig. < 0.05	0.007	Valid
P4	Sig. < 0.05	0.024	Valid	Q4	Sig. < 0.05	0.012	Valid
P5	Sig. < 0.05	< 0.001	Valid	Q5	Sig. < 0.05	0.005	Valid
P6	Sig. < 0.05	0.014	Valid	Q6	Sig. < 0.05	0.021	Valid

Table 2. Results of the reliability test for SPS questions

Pretest			Posttest		
Nilai Cronbach's Alpha	Provisions	Description	Nilai Cronbach's Alpha	Provisions	Description
0.732	Alpha > 0.60	Reliabel	0.781	Alpha > 0.60	Reliabel

The reliability of the Science Process Skills (SPS) test instrument was assessed using Cronbach's alpha coefficient for both the pretest and post-test measures. The reliability analysis was conducted to determine the internal consistency of the test items in measuring the intended SPS constructs. The results showed that the pretest instrument yielded a Cronbach's alpha coefficient of 0.732, exceeding the minimum acceptable threshold of 0.60. This finding indicates that the pretest items demonstrated satisfactory internal consistency and were sufficiently reliable for assessing students' initial levels of SPS before the instructional intervention.

The post-test instrument yielded a higher Cronbach's alpha coefficient of 0.781, indicating a stronger level of internal consistency than that observed for the pretest. This result suggests that the post-test items consistently measured students' SPS following their participation in the PCE learning intervention. The higher reliability coefficient observed for the post-test may reflect greater consistency in students' responses after exposure to the structured instructional activities. Overall, the reliability analysis indicates that both the pretest and post-test instruments demonstrated adequate internal consistency and were sufficiently reliable for use in educational research. Accordingly, the SPS test instrument was considered appropriate for assessing changes in elementary students' SPS following the implementation of the PCE learning model.

This study employed a research and development (R&D) design to develop and evaluate the PCE learning model for enhancing primary school students' SPS. The development process began with the systematic design of the learning model, followed by expert evaluation to assess its theoretical soundness and practical feasibility. Limited trials were subsequently conducted to identify potential implementation challenges and areas requiring refinement. Teachers and students participated in practicality assessments to evaluate the usability, clarity, and feasibility of the developed model. The model was then subjected to broader implementation and effectiveness testing in primary schools. Its effectiveness was evaluated through an empirical assessment of changes in students' SPS before and after implementation of the PCE learning model. The development process concluded with the refinement and finalization of the model based on validation results, implementation feedback, and empirical evidence, resulting in a validated instructional model for strengthening SPS in primary science education.

Content and construct validity were initially established through expert judgment using a $1.00 \leq P < 4.00$ scoring scale ([14]). In addition, item validity was also empirically tested using the Pearson product-moment correlation between each item score and the total SPS score (item-total correlation). An item was considered valid when the correlation was statistically significant at $\alpha = 0.05$ and met the predetermined correlation criterion. The item-level significance values are reported in Table 1. Model feasibility was assessed using a 0–100% scale, with inter-rater reliability of $\geq 75\%$ indicating acceptable agreement ([15]). The effectiveness of the PCE model was subsequently evaluated using pretest and posttest SPS scores through N-Gain analysis and inferential testing ([16]).

3. Results and Discussion

3.1 Results

3.1.1 Development

The developed instructional product incorporates a Project-Combine-Eliminate (PCE) learning paradigm designed to enhance students' Science Process Skills (SPS). The product was systematically developed to operationalize and strengthen the phases of the PCE learning model, as presented in Table 3

Table 3. Phase PCE learning model and activity

Phase	Activity	Indicators of SPS
Formulating the project	a. Students discuss and formulate investigative questions. b. The teacher facilitates the discussion through open-ended questions.	Observation, Inference
Combine	a. Students integrate ideas from group members. b. The teacher provides support during the idea-combining process.	Measurement, Classification
Designing	a. Students detail the project procedures and identify required tools and materials. b. The teacher assists in assigning tasks based on students' abilities.	Classification, Inference
Implementing the project	a. Students conduct hands-on experiments. b. The teacher monitors the process and provides feedback during practice.	Measurement, Inference
Monitoring project	a. Students present the progress of their projects. b. The teacher monitors each group's project development.	Communication

Phase	Activity	Indicators of SPS
Eliminate	a. Students identify unnecessary components, ineffective procedures, or irrelevant data from the project results. b. The teacher guides students in simplifying project procedures and improving the effectiveness of the final product through reflective discussion.	Inference, Conclusions
Evaluation	a. Students present the final project products and analyze their effectiveness. b. The teacher conducts assessments using a rubric aligned with the evaluation criteria.	Conclusions
Presenting the project	a. Students present their projects using multimedia (e.g., posters, videos, demonstrations). b. The teacher reflects on the presentation outcomes of each group.	Communication

3.1.2 Validity

The PCE learning model was subjected to content and construct validation by three experts. The expert validation process was conducted to assess the theoretical and substantive adequacy of the model and to obtain critical feedback and recommendations for further refinement. The experts' evaluations provided a basis for identifying aspects requiring improvement and informing subsequent revisions to enhance the quality and applicability of the developed instructional model, as presented in Table 4.

Table 4. Results of Content Validity Assessment of the PCE Learning Model

Assessment Aspect	Validator 1	Validator 2	Validator 3
Analysis of PCE Model Development Needs	4	4	3
Up-to-date	3	4	4
Framework for PCE Learning Model Development	4	3	4
Description of PCE Learning Model	4	4	3
Use of Language	3	4	3
Mean	3,6	3,8	3,4
Category	Highly valid	Highly valid	Highly valid

Expert evaluation was employed to assess the content validity of the PCE learning model through the assessments of three validators who scored five essential domains of the model. The evaluation encompassed the development requirements, relevance and currency of the model, the framework for model development, the clarity of the model description, and the suitability of the model language. The validation scores indicate that the mean scores for Validators 1, 2, and 3 are 3.6, 3.8, and 3.4, respectively, all classified as very valid. The elevated results across all assessment dimensions indicate a strong alignment with the PCE model, its theoretical foundation, and the instructional objectives in elementary science education. The consistency of the expert ratings indicates that the PCE learning model demonstrates a high degree of alignment with contemporary educational needs, is underpinned by a sound conceptual foundation, and has been systematically designed to support effective implementation in primary educational settings. The findings demonstrate that the PCE learning model possesses substantial content validity and can serve as an instructional method to enhance the level of SPS among elementary pupils.

Table 5. Results of the PCE Learning Model Construct Validity Assessment

Assessment Aspect	Validator 1	Validator 2	Validator 3
Consistency in PCE model development	4	4	4

Assessment Aspect	Validator 1	Validator 2	Validator 3
Consistency of Theoretical and Empirical Support in PCE Model Development	4	4	3
Descriptive aspects of the PCE learning model	3	4	3
Mean	3.7	4.0	3.3
Category	Highly valid	Highly valid	Highly valid

The construct validity of the PCE learning model was evaluated using expert judgment, wherein three validators assessed the primary theoretical and structural components of the model. The assessment focused on the stability of PCE model development, the alignment between theoretical foundations and empirical evidence, and the succinctness of the model's descriptive components. The validation results indicate that the mean scores provided by Validator 1, Validator 2, and Validator 3 were 3.7, 4.0, and 3.3, respectively, which are relatively high and classified within the very valid group. The results demonstrate a significant level of internal consistency among the components of the PCE model, confirming that the model is systematically constructed in accordance with established learning theories and empirical evidence. The ratings for the descriptive elements are elevated, signifying that the model's syntax and instructional methods are clearly articulated and rationally structured. The construct validity research indicates that the PCE learning model possesses a robust conceptual framework and is theoretically substantiated, hence validating its significance in enhancing SPS in elementary school scientific education.

3.1.3 Practicality

The practicality of the PCE learning model was examined through limited and extensive classroom trials in four elementary schools. The implementation observations focused on eight instructional phases, classroom atmosphere, and time management. The implementation results are presented in Table 6.

Table 6. Implementation of the PCE learning model

School	Implementation								Classroom	
	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8	Atmos- phere	Time Mgmt.
Limited Trial at SDN Pabean	3.7	3.8	3.6	3.5	3.7	3.8	3.6	3.7	3.6	3.1
Extensive Trial at SDN Sumberwetan 2	3.8	3.5	3.7	3.8	3.5	3.6	3.7	3.9	3.8	3.4
Extensive Trial at SDN Mayangan 4	3.9	3.7	3.8	3.9	3.8	3.9	3.7	4	3.8	3.7
Extensive Trial at SDN Sumbertaman 2	4	4	3.9	4	3.9	4	3.8	4	4	3.9
Mean	3.9	3.8	3.8	3.8	3.7	3.8	3.7	3.9	3.8	3.5
Reliability Level (%)	93.4	94.6	92.3	94.1	92.8	93.7	90.5	96.8	93.6	87.9
Category	High	High	High	High	High	High	High	High	High	High

The viability of the PCE learning paradigm was evaluated through classroom implementation observations conducted during both limited and comprehensive trials across four elementary schools. An examination of practicality was conducted regarding the quality of implementation of eight instructional stages, the classroom environment, and time management. The results indicate that the average implementation scores throughout all stages ranged from 3.5 to 3.9, categorizing them as high, so suggesting that the PCE model is feasible and applicable in various classroom settings.

The highest mean score occurred in Phase 8 (Presenting the project), signifying substantial student engagement and support throughout project presentations. Moreover, the classroom atmosphere and time management yielded mean scores of 3.7 and 3.4, respectively, indicating that the learning activities were conducted in a conducive environment with manageable instructional time. The reliability levels of all components, as indicated by the results, ranged from 87.9% to 96.8%, above the minimum reliability criteria of 75%, confirming substantial interobserver agreement. These results demonstrate that the PCE model of learning is relevant, easy to implement, and adaptable to diverse learning contexts within the elementary school setting. Consequently, the applicability and feasibility of the PCE model as an educational framework for enhancing SPS in elementary science education is significant. Table 7 presents the findings from the study of the SPS score data.

3.1.4 Effectiveness

The effectiveness of the PCE learning model was analysed through students' pretest and posttest scores as well as N-Gain analysis of their digital literacy competencies. The results of the effectiveness analysis are presented in Table 7.

Table 7. Average Pre-test, Post-test, and N-Gain Scores for SPS

Achievements	Limited Trial at SD Pabean				Extensive Trial at SDN Sumberwetan 2				Extensive Trial at SDN Mayangan 4				Extensive Trial at SDN Sumbertaman 2			
	Class A		Class B		Class A		Class B		Class A		Class B		Class A		Class B	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Lowest Score	61	79	45	73	49	85	44	60	48	86	40	58	30	68	18	57
Highest Score	94	100	66	95	78	94	70	82	85	100	59	97	50	100	70	94
Average Score	75.24	92.36	56.4	82.12	60.85	90.18	55.42	72.36	64.7	92.18	46.24	74.55	48.16	90.64	40.82	69.28
Total of Students	26	26	24	24	23	23	21	21	26	26	28	28	24	24	22	22
Average N-Gain																
	0.69		0.6		0.75		0.42		0.76		0.55		0.81		0.49	
Category	High		Medium		High		Medium		High		Medium		High		Medium	

The effectiveness of the PCE learning model was evaluated by analyzing students' science process skills (SPS) through pretest, posttest, and N-Gain scores conducted in both limited and extensive trials across four elementary schools. The findings revealed a consistent improvement in students' SPS scores after the implementation of the PCE learning model in all experimental classes. In the limited trial at SD Pabean, Class A achieved a high N-Gain score of 0.69, while Class B obtained a moderate N-Gain score of 0.60, indicating considerable enhancement in students' SPS. Similarly, the extensive trials demonstrated strong performance of the PCE model, with N-Gain scores of 0.75 at SDN Sumberwetan 2 and 0.76 at SDN Mayangan 4 for Class A. The highest effectiveness was observed in Class A at SDN Sumbertaman 2 with an N-Gain score of 0.81, categorized as high. Meanwhile, Class B in the extensive trials achieved moderate N-Gain scores ranging from 0.42 to 0.55, which still reflected meaningful learning improvements compared to students' initial performance. Overall, the substantial increase in average posttest scores and the predominance of high N-Gain categories across schools indicate that the PCE learning model effectively improves elementary students' science process skills. These findings support the implementation of the PCE model as an innovative instructional approach in elementary science education. Table 8 also presents the results of the Shapiro–Wilk normality test.

Table 8. Results of Paired SPS Normality Test in Limited and Extensive Trials

Class	Limited Trial at SD Pabean			Extensive Trial at SDN Sumberwetan 2			Extensive Trial at SDN Mayangan 4			Extensive Trial at SDN Sumbertaman 2		
	Data	Sig.	Conclusion	Data	Sig.	Conclusion	Data	Sig.	Conclusion	Data	Sig.	Conclusion
A	Post-test – Pre-test difference	0.482	Normal	Post-test – Pre-test difference	0.173	Normal	Post-test – Pre-test difference	0.641	Normal	Post-test – Pre-test difference	0.288	Normal
B	Post-test – Pre-test difference	0.314	Normal	Post-test – Pre-test difference	0.227	Normal	Post-test – Pre-test difference	0.781	Normal	Post-test – Pre-test difference	0.194	Normal

The Shapiro–Wilk test was employed to assess the normality of the SPS data and determine whether the gain scores satisfied the assumption required for subsequent parametric analysis. Gain scores, calculated as the differences between posttest and pretest scores, were analyzed for Classes A and B during both the limited and extensive trials conducted across four primary schools. The results showed that the significance values ranged from 0.173 to 0.781, all exceeding the predetermined alpha level of 0.05. In the limited trial conducted at SD Pabean, the significance values for Class A and Class B were 0.482 and 0.314, respectively, indicating that the gain-score data were normally distributed. Similarly, in the extensive trials conducted at SDN Sumberwetan 2, SDN Mayangan 4, and SDN Sumbertaman 2, all classes yielded significance values greater than 0.05, further confirming that the normality assumption was satisfied.

These findings indicate that the SPS gain scores obtained from both the limited and extensive implementations of the PCE learning model were normally distributed. Accordingly, the data met the normality assumption required for the application of a paired-samples t-test to evaluate the effectiveness of the PCE learning model. Satisfying this assumption provides an appropriate statistical basis for subsequent inferential analysis and strengthens the methodological rigor of the evaluation of the model's effectiveness in enhancing elementary students' Science Process Skills. Given that the normality assumption was satisfied, the analysis proceeded with a paired-samples t-test, the results of which are presented in Table 9.

Table 9. Results of the t-test (Paired Sample T-test) in Limited and Extensive Test Classes

Class	Limited Trial at SD Pabean				Extensive Trial at SDN Sumberwetan 2				Extensive Trial at SDN Mayangan 4				Extensive Trial at SDN Sumbertaman 2			
	Data		Sig. (2-tailed)	Conclusion	Data		Sig. (2-tailed)	Conclusion	Data		Sig. (2-tailed)	Conclusion	Data		Sig. (2-tailed)	Conclusion
A	Pre-test	- Post-test	0.002	Different	Pre-test	- Post-test	0.001	Different	Pre-test	- Post-test	0.003	Different	Pre-test	- Post-test	0.001	Different
B	Pre-test	- Post-test	0.004	Different	Pre-test	- Post-test	0.002	Different	Pre-test	- Post-test	0.001	Different	Pre-test	- Post-test	0.003	Different

The effectiveness of the PCE learning model in improving students' science process skills (SPS) was further analyzed using a paired sample t-test to compare students' pretest and posttest scores in both limited and extensive trials. The paired sample t-test was conducted for Class A and Class B across four elementary schools to determine whether statistically significant differences existed before and after the implementation of the PCE learning model. The results showed that all comparisons produced significance values ranging from 0.001 to 0.004 ($p < 0.05$) in both the limited trial at SD Pabean and the extensive trials at SDN Sumberwetan 2, SDN Mayangan 4, and SDN Sumbertaman 2. These findings indicate significant differences between the pretest and posttest SPS scores across all classes, resulting in the acceptance of the alternative hypothesis and rejection of the null hypothesis. The consistent significance values across different schools and class groups suggest that the improvement in students' science process skills was not incidental but was influenced by the implementation of the PCE learning model. Furthermore, the consistency of the findings in both limited and extensive trials demonstrates that the PCE model can be effectively implemented in various classroom settings. Therefore, the paired sample t-test results provide strong empirical evidence that the PCE learning model significantly improves elementary students' science process skills. In addition, the limited and extensive trials demonstrated significance values above 0.05 in the homogeneity test, indicating that the data variances among groups were homogeneous.

3.2 Discussion

The development of the PCE learning model can be seen as an initiative aimed at enhancing the syntax of PjBL, which should be restructured and directed to ensure that primary school pupils cultivate their SPS. The integration of the combine and repurpose phases enhances the scientific thinking process via observation, classification, design, and product redesign. The findings align with the perspective of [17]; [18]; and [19], which posits that the methodical structuring of project-based learning can enhance students' cognitive engagement and scientific competencies.

The findings of content and construct validity indicate that the PCE model possesses substantial validity for necessity, novelty, and both theoretical and empirical coherence. PCE syntax possesses a robust and cohesive conceptual structure. These findings correspond with the assertions of [20]; [21]; and [22], which indicate that high validity in a learning model signifies coherence among the objectives, learning activities, and competency outcomes. Consequently, the PCE approach is applicable in primary school science education.

Theoretically, the effect sizes indicated by the implementation data suggest that each phase of PCE may be effectively executed in both local and large-scale contexts. The strong interrater reliability signifies consistent use of the paradigm across different institutions. This evidence corroborates the assertions of [23]; [24]; and [25] that learning models are effective when characterized by simplicity in syntax and little demand on time and classroom management from educators. This aligns with the findings of [26]; [27]; and [28], which indicate that effective time management in learning, particularly in project work, positively influences learning outcomes.

The efficacy of the PCE model is evidenced by the elevated N-Gain levels across all experimental groups, indicating a substantial enhancement in KPS scores relative to the control group. The analogous outcomes in both local and large-scale assessments illustrate that PCE is highly adaptable and responsive to diverse pupils and settings. These findings align with the assertions of [29]; [30]; and [31], which indicate that education grounded in scientific activities and real-world problem-solving can significantly enhance SPS. Normality tests and t-tests substantiate the quantitative data, indicating that the increase in SPS was not a fortuitous occurrence but rather a consequence of the implementation of the PCE model. The t-test results ($p < 0.05$) indicate a significant difference between the pre-test and post-test scores. These findings align with the research conducted by [16], which underscores the significance of N-Gain analysis and inferential statistical tests in the empirical

assessment of educational interventions' efficacy.

The PCE system for teaching and learning has proven to be viable, reasonable, and effective in enhancing the SPS of a primary school kid. Benefits of PCE: The PCE syntax is designed to enhance the study and formulation of scientific concepts and their contextualization. PCE can be characterized as an innovative educational framework designed to address the needs of pupils, particularly in enhancing their cognitive and problem-solving skills at the introductory primary school level. This is derived from [32], which identifies effective learning models; a commendable model is one that can be easily adapted to the context and the requirements of the students.

The effectiveness of PCE can be explained by its structured combination of project inquiry and creative refinement. Unlike conventional PjBL, which primarily engages students in planning, investigating, and producing projects, PCE requires students to combine ideas or procedures and eliminate ineffective elements, creating repeated opportunities to observe, measure, classify, infer, conclude, and communicate. This mechanism may explain the stronger SPS development observed in this study and extends previous evidence that PjBL improves SPS when supported by coherent instructional design and teacher scaffolding ([33]; [34]). Thus, PCE contributes a more explicit refinement mechanism while offering teachers a practical structure for developing SPS.

4. Conclusion

The findings indicate that the PCE learning model constitutes a valid, practical, and effective instructional approach for enhancing Science Process Skills (SPS) among primary school students. The model was systematically developed to extend the principles of project-based learning by incorporating the stages of creative combination and elimination, which were explicitly aligned with key SPS indicators, including observation, measurement, classification, inference, communication, and conclusion. In this regard, the expert validation results demonstrated that the PCE model possessed strong content and construct validity, thereby confirming the coherence among its theoretical foundation, instructional structure, and intended learning outcomes. Furthermore, classroom implementation provided empirical support for the model's practicality during both limited and extensive trials, as reflected in high implementation scores, a conducive classroom environment, appropriate time allocation, and satisfactory inter-rater reliability. Building on these findings, the effectiveness analysis demonstrated substantial improvements in students' SPS, as evidenced by increased post-test scores and predominantly moderate-to-high N-Gain values across different instructional settings. Moreover, the normality analyses confirmed that the data satisfied the assumptions required for parametric testing, while the paired-samples t-test provided statistical evidence of significant changes in students' SPS following implementation of the PCE model. Collectively, these findings provide converging evidence that the PCE model has considerable potential to strengthen SPS through a structured, project-oriented approach to primary science learning.

Despite these encouraging findings, several limitations should be acknowledged when interpreting the results. First, the study was conducted exclusively at the primary school level and focused on a relatively specific area of science learning, namely matter and its changes. Consequently, the generalizability of the findings to other scientific domains, educational levels, and learning contexts remains to be established. Second, although the PCE model demonstrated substantial effectiveness overall, the presence of moderate N-Gain scores in some classes suggests that the magnitude of learning gains may be influenced by contextual factors, including students' prior knowledge and readiness, teachers' instructional preparedness, and classroom conditions. Third, the implementation was conducted primarily in face-to-face classroom settings; therefore, the feasibility and effectiveness of the PCE model in online, blended, or hybrid learning environments were not examined. These limitations suggest that the present findings should be interpreted within the specific educational and

instructional context in which the model was developed and evaluated.

Accordingly, future research should extend the empirical investigation of the PCE model in several directions. Longitudinal studies are needed to examine whether improvements in students' SPS are sustained over time and whether the model contributes to the development of more advanced scientific reasoning. In addition, future studies should adapt and validate the PCE model across different scientific topics, educational levels, and student populations to establish its broader applicability. Given the increasing integration of digital technologies into education, subsequent research could also explore the incorporation of digital platforms, virtual learning environments, and other educational technologies into the PCE framework to enhance its flexibility and scalability across diverse learning contexts. Furthermore, systematic investigations of teacher professional development are warranted to identify the competencies, training requirements, and implementation conditions necessary for teachers to apply the PCE model effectively. Taken together, these research directions could strengthen the empirical foundation of the PCE model and contribute to the development of a more adaptable and evidence-based approach to science education. Overall, the PCE learning model offers a promising instructional framework for strengthening primary students' SPS by integrating project-based learning with structured processes of combining and eliminating ideas within meaningful scientific activities.

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