

The Effect of a Deep Learning-Based Scientific Collaboration Model on Fifth-Grade Students' Learning Outcomes

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ABSTRACT

This study aimed to determine the effect of the Deep Learning-based Scientific Collaboration (SCICOLLA) model on fifth-grade students' learning outcomes in Science and Social Studies (IPAS) at SD Negeri Sabrang Lor No. 78 Surakarta. A quantitative pre-experimental study with a one-group pretest–posttest design was conducted with 27 students selected through total sampling. Learning outcomes were measured using a validated and reliable multiple-choice test of Higher-Order Thinking Skills (HOTS), supported by observation, interviews, and documentation. The data were analyzed using the Shapiro–Wilk normality test, the paired sample t-test, the Wilcoxon signed-rank test, and N-Gain analysis. Students' mean learning outcome increased from 59.07 on the pretest to 87.41 on the posttest, and the minimum score rose from 27 to 60. The paired sample t-test ($t = 13.969$, $p < 0.001$) and the Wilcoxon signed-rank test ($p = 0.001$) showed a significant difference, and the N-Gain score of 0.717 was in the high category. These findings indicate that the Deep Learning-based SCICOLLA model, through mindful, meaningful, and joyful collaborative inquiry, has a significant positive effect on fifth-grade students' learning outcomes.

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Introduction

National Education is based on Law of the Republic of Indonesia Number 20 of 2003, which mandates the development of students' potential to become capable, creative, independent, and responsible individuals. Responding to the global challenges of the 21st century, education no longer merely requires the transfer of knowledge, but a paradigm shift toward deep learning that targets six global competencies (6C): character, citizenship, collaboration, communication, creativity, and critical thinking (Kemendikbudristek, 2022; Suyanto, 2025). Deep learning is realized through mindful, meaningful, and joyful (MMJ) learning experiences (Diputera et al., 2024), and recent literature reviews position it as a

strategy that fits the Merdeka Curriculum and supports 21st-century competencies (Kharisma et al., 2025; Khotimah & Abdan, 2025; Sari & Arta, 2025). In the Merdeka Curriculum, the Science and Social Studies (IPAS) subject in the fifth grade is an ideal platform for integrating this approach because it is designed to build scientific reasoning and science literacy while developing social awareness (Fitriah et al., 2023; Sundari & Bintoro, 2025).

However, the reality in the field indicates a significant gap. Based on observations at SD Negeri Sabrang Lor No. 78 Surakarta, learning had not yet touched the essence of deep learning because students tended to be afraid of making mistakes and were passive in expressing their opinions. As a result, students' conceptual understanding remained at the level of surface learning, which is difficult to apply in solving real-world problems. This was confirmed by the pretest results on a Higher Order Thinking Skills (HOTS) instrument, in which the class average was only 59.07. HOTS-based assessment is an appropriate way to reveal such limitations because it requires students to analyze, evaluate, and create rather than recall facts (Kasdina et al., 2023). The challenges of implementing deep learning in elementary schools, such as teacher readiness and the translation of the concept into classroom practice, have also been highlighted (Isnayanti et al., 2025; Tsuraya et al., 2025).

To overcome these problems, an intervention was implemented using the Deep Learning-based SCICOLLA model. SCICOLLA combines a scientific inquiry approach with structured teamwork, so that the risk of failure is shared and student anxiety is reduced. Its syntax shifts the paradigm from teacher-centered to student-centered learning, consistently facilitated by the pillars of mindful, meaningful, and joyful learning. Previous research by Handini (2021) and Handini et al. (2021a, 2021b) showed that SCICOLLA effectively increased students' classical cognitive learning mastery, and teachers at the research school have been trained to design lessons with this model (Handini et al., 2025). In line with this, the deep learning approach has been reported to improve fifth-grade IPAS learning outcomes (Mariani et al., 2025) and learning in other elementary subjects (Kurniawan, 2025; Mutmainnah et al., 2025), while collaborative learning has been shown to improve IPAS learning outcomes (Sinaga et al., 2025).

Learning outcomes in IPAS are not limited to the recall of facts but include students' ability to apply, analyze, evaluate, and create knowledge, which corresponds to higher-order thinking skills (Kasdina et al., 2023). Such outcomes are more likely to develop when students are mentally engaged, find the material relevant to their lives, and feel safe to participate, which are the core principles of mindful, meaningful, and joyful learning in the deep learning approach (Diputera et al., 2024; Suyanto, 2025). Collaborative learning further supports these outcomes because students exchange ideas, test their understanding, and correct misconceptions through interaction with peers (Sinaga et al., 2025). Accordingly, a learning model that integrates scientific inquiry, collaboration, and deep learning principles is expected to improve fifth-grade students' learning outcomes more substantially than learning that emphasizes memorization (Kharisma et al., 2025; Sari & Arta, 2025).

The novelty of this research lies in the specific integration of the SCICOLLA model with deep learning elements in the interdisciplinary content of IPAS. Therefore, this study aims to examine and analyze the extent to which the application of the Deep Learning-based SCICOLLA model affects higher-order cognitive learning outcomes of fifth-grade students at SD Negeri Sabrang Lor No. 78 Surakarta.

Method

This research is quantitative research with a pre-experimental method. The design used was the one-group pretest-posttest design, in which observations are made before and after the treatment (Sugiyono, 2023). The research was conducted at SD Negeri Sabrang Lor No. 78 Surakarta from October 2025 to June 2026. The population was all fifth-grade students in the 2025/2026 academic year, totaling 27 students. The sample was drawn using a total sampling technique, meaning that all members of the population were used as the research sample (Sugiyono, 2023).

The research procedure consisted of three stages. In the first stage, students took a pretest to measure their initial learning outcomes. In the second stage, the Deep Learning-based SCICOLLA model was implemented in IPAS learning on the distribution of flora and fauna, with every learning activity designed to fulfil the mindful, meaningful, and joyful principles. In the third stage, students took a posttest with the same HOTS instrument, and the pretest and posttest data were analyzed. The procedure is presented in Figure 1.

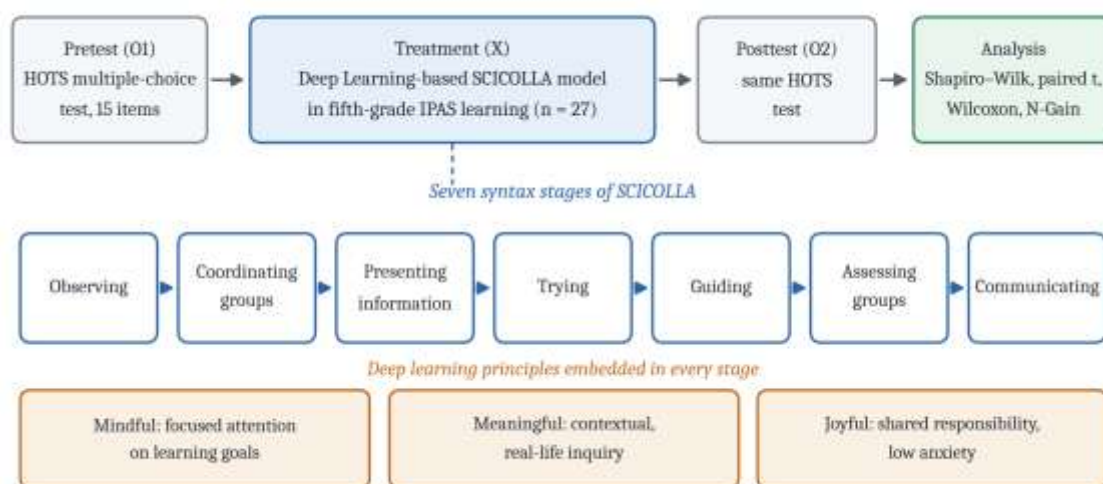


Figure 1. Research Procedure and Syntax of the Deep Learning-Based SCICOLLA Model

Data were collected through a multiple-choice test (15 questions based on the C3, C4, C5, and C6 cognitive indicators on the material of flora and fauna distribution), supported by interviews, observation of syntax implementation, and documentation. The test items followed the principles of HOTS-based assessment (Kasdina et al., 2023). The instrument had been tried out beforehand, met the requirements of construct validity (Pearson Product Moment), and had a high level of reliability with a Cronbach's alpha of 0.790. The learning process followed the seven syntax stages of SCICOLLA (Handini et al., 2021a). Data were analyzed using the Shapiro-Wilk normality test as a prerequisite, followed by hypothesis testing using the paired sample t-test, supported by the non-parametric Wilcoxon signed-rank test (Sugiyono, 2023). The effectiveness of the improvement in learning outcomes was measured using normalized gain (N-Gain) analysis.

The implementation of the SCICOLLA syntax in this study and the deep learning principles facilitated at each stage are summarized in Table 1. The syntax was adapted

from the SCICOLLA model developed by Handini et al. (2021a) and integrated with the mindful, meaningful, and joyful principles of deep learning (Diputera et al., 2024).

Table 1. Syntax of the Deep Learning-Based SCICOLLA Model and the Deep Learning Principles Facilitated

SCICOLLA Stage	Learning Activities	Deep Learning Principle
Observing	Students observe contextual phenomena related to the distribution of flora and fauna and formulate questions.	Mindful, meaningful
Coordinating groups	The teacher forms heterogeneous groups, and students divide roles and responsibilities.	Joyful
Presenting information	The teacher and students present key information and learning resources needed for the inquiry.	Mindful
Trying	Groups investigate the problem, collect and process information, and construct answers together.	Meaningful, joyful
Guiding	The teacher provides scaffolding and guiding questions while groups work.	Mindful
Assessing groups	Groups assess their own and other groups' work using clear criteria.	Mindful, meaningful
Communicating	Groups present their conclusions, respond to questions, and reflect on their learning.	Meaningful, joyful

Source: Adapted from Handini et al. (2021a) and Diputera et al. (2024).

Results and Discussion

Based on the data collected from 27 respondents, the initial condition of the students' cognitive learning outcomes before the treatment (pretest) was still relatively low. The average pretest score was 59.07, with the lowest score of 27 and the highest score of 80, as shown in Table 2 and Figure 2. This low initial achievement indicates that students had difficulties in answering questions with HOTS dimensions because of the dominance of previous learning oriented toward surface learning (Diputera et al., 2024; Kasdina et al., 2023).

Table 2. Descriptive Statistics of Pretest and Posttest Scores

Descriptive Statistics	Pretest	Posttest
N	27	27
Mean	59.07	87.41
Maximum score	80	100
Minimum score	27	60

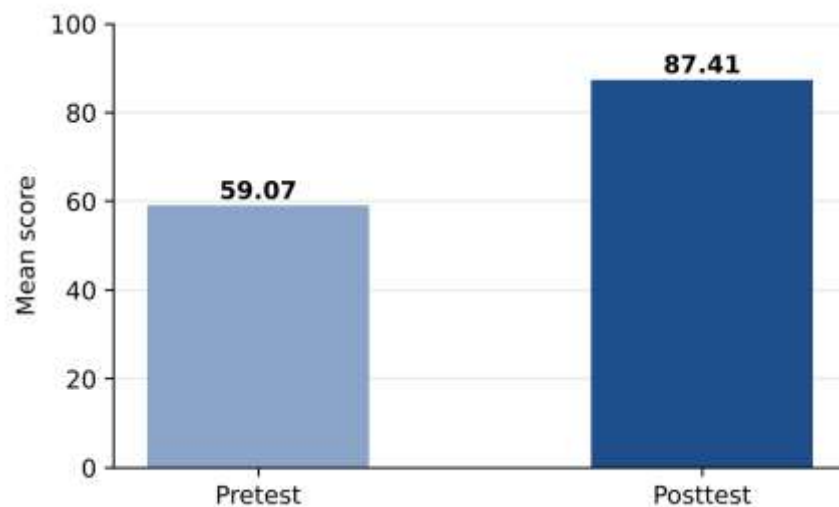


Figure 2. Mean Pretest and Posttest Scores of Students' IPAS Learning Outcomes

After the treatment using the Deep Learning-based SCICOLLA learning model, academic achievement increased considerably. The learning process through the seven syntax stages (observing, coordinating groups, presenting information, trying, guiding, assessing groups, and communicating) facilitated the elements of mindful, meaningful, and joyful learning. The final evaluation (posttest) recorded an increase in the average score to 87.41, with a minimum score of 60 and a maximum score of 100. Figure 3 shows that the minimum, mean, and maximum scores all increased, and the minimum score rose most sharply, from 27 to 60.

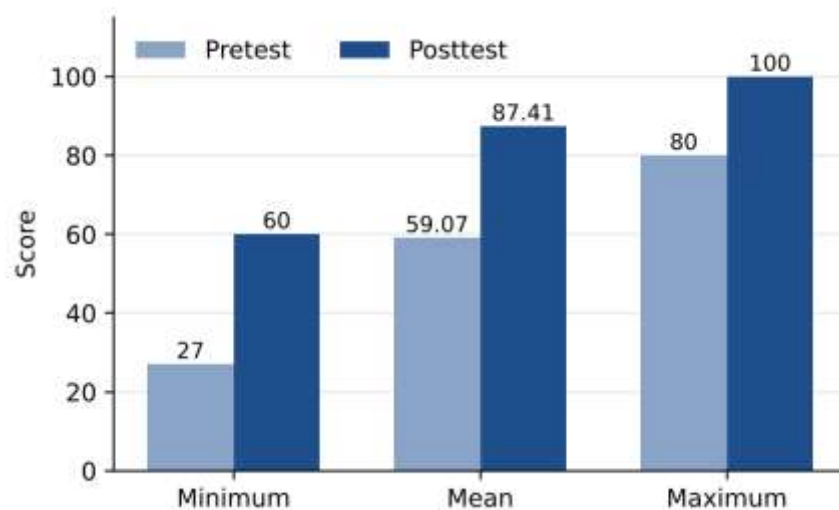


Figure 3. Minimum, Mean, and Maximum Scores of Pretest and Posttest

To prove the significance of this increase, statistical testing was conducted using SPSS. The prerequisite Shapiro-Wilk normality test (Table 3) showed a significance value of 0.113 for the pretest (normally distributed), while the posttest showed 0.012 (not normally distributed).

Table 3. Results of the Shapiro-Wilk Normality Test

Data	Sig. (Shapiro-Wilk)	Description
Pretest	0.113	Normally distributed (> 0.05)
Posttest	0.012	Not normally distributed (< 0.05)

Because one data set was not normally distributed, hypothesis testing was carried out using two approaches: a parametric test (paired sample t-test), and a non-parametric validation test (Wilcoxon signed ranks test). As presented in Table 4, the paired sample t-test obtained a t count of 13.969, which far exceeded the t table value of 2.056, with a two-tailed significance of $p < 0.001$. The Wilcoxon test confirmed the consistency of these results with an asymptotic significance of $0.001 < 0.05$, so H_0 was rejected by both tests.

Table 4. Results of Hypothesis Tests and N-Gain Analysis

Test	Result	Sig.	Interpretation
Paired sample t-test	t count = 13.969 (t table = 2.056)	0.000	H_0 rejected
Wilcoxon signed ranks test	Asymp. Sig. (2-tailed)	0.001	H_0 rejected
N-Gain	0.717 (71.7%)	–	High (> 0.70)

Furthermore, the effect of the treatment was examined using the N-Gain test. The average N-Gain score reached 0.717, or 71.7% in percentage terms. Based on the evaluation criteria, a score above 0.70 indicates that the application of the model has a high level of effectiveness on students' cognitive achievement.

In absolute terms, students' mean score increased by 28.34 points, or 47.98% of the pretest mean. The score range also narrowed from 53 points on the pretest (27–80) to 40 points on the posttest (60–100), indicating that the improvement was experienced by students at different initial levels, including those with the lowest initial scores. This pattern suggests that the collaborative structure of SCICOLLA allowed students with lower initial achievement to benefit from interaction with their peers, which is consistent with the finding that collaborative learning improves IPAS learning outcomes (Sinaga et al., 2025).

This significant improvement is inseparable from the characteristics of the SCICOLLA model, which reduces students' psychological barriers (fear of being wrong) by sharing responsibility in teamwork, so that learning becomes highly student-centered. These findings reinforce Handini (2021) and Handini et al. (2021a, 2021b), who stated that the fusion of scientific and collaborative approaches in SCICOLLA can make the learning atmosphere more active and profound. The result is also consistent with Mariani et al. (2025), who reported that the deep learning approach improved fifth-grade IPAS learning outcomes, and with Sinaga et al. (2025), who found that collaborative learning improved IPAS learning outcomes. Similar benefits of the deep learning approach have been reported in elementary mathematics (Mutmainnah et al., 2025) and in differentiated instruction (Kurniawan, 2025).

Each stage of the SCICOLLA syntax contributed to the improvement of students' learning outcomes. The observing and presenting information stages directed students'

attention to the learning goals and activated their prior knowledge, reflecting mindful learning. The trying and communicating stages required students to connect the concept of flora and fauna distribution with real situations, investigate it, and explain their conclusions, reflecting meaningful learning. Meanwhile, coordinating groups and assessing groups created a supportive atmosphere in which responsibility was shared and mistakes were treated as part of learning, reflecting joyful learning. These experiences are in line with the characteristics of deep learning described in recent studies (Diputera et al., 2024; Khotimah & Abdan, 2025; Suyanto, 2025).

From a theoretical perspective, the findings support the view that mindful, meaningful, and joyful learning (Diputera et al., 2024) combined with the development of collaboration and critical reasoning, as part of the 21st-century competencies, can deepen students' understanding (Kharisma et al., 2025; Khotimah & Abdan, 2025; Sari & Arta, 2025). The large gain in HOTS-based scores suggests that structured group inquiry helps students move beyond memorization, which is in line with the importance of fostering science process skills and conceptual understanding in IPAS learning (Fitriah et al., 2023; Sundari et al., 2025; Sundari & Bintoro, 2025).

The improvement of learning outcomes measured with HOTS items also indicates that students did not merely memorize information but were able to analyze, evaluate, and create answers to contextual problems. HOTS-based assessment is suitable for capturing such outcomes because it demands reasoning beyond recall (Kasdina et al., 2023). Learning materials and worksheets designed to guide inquiry and science literacy have likewise been shown to strengthen elementary students' conceptual understanding (Fitriah et al., 2023; Sundari et al., 2025), and the integration of technology, pedagogy, and content can further enrich such learning (Sundari & Bintoro, 2025). Therefore, the effect of SCICOLLA on learning outcomes is best understood as the combined effect of structured inquiry, peer collaboration, and a learning climate that makes students willing to think deeply.

In practical terms, teachers can adopt SCICOLLA to make IPAS learning more collaborative and inquiry-oriented, provided that they are well prepared to design such lessons (Handini et al., 2025; Isnayanti et al., 2025). At the policy level, the results support efforts to implement deep learning systematically in primary education (Tsuraya et al., 2025). The results should nevertheless be interpreted with caution because the study involved a small sample ($N = 27$) from a single school and had no control group.

Future studies are recommended to use a quasi-experimental design with a control group, involve larger samples from several schools, measure learning outcomes on each cognitive level from C3 to C6, and examine affective outcomes such as collaboration and confidence. Such studies would provide stronger evidence on how the Deep Learning-based SCICOLLA model affects elementary students' learning outcomes across different IPAS topics (Mariani et al., 2025; Tsuraya et al., 2025).

Conclusion

The application of the Deep Learning-based Scientific Collaboration (SCICOLLA) learning model has a positive and significant effect on improving the cognitive IPAS learning outcomes of fifth-grade students at SD Negeri Sabrang Lor No. 78 Surakarta, as evidenced by the increase in the average score from 59.07 to 87.41 with a high N-Gain of 0.717, and by hypothesis tests (paired sample t-test, $p < 0.001$, and Wilcoxon signed ranks test, $p = 0.001$) that consistently rejected H_0 , which indicates that a scientific, collaborative, and meaningful learning ecosystem can overcome students' surface learning

habits. Because this study used a design without a control group, future research is recommended to adopt a quasi-experimental design to minimize confounding variables and to observe the strengthening of student character longitudinally.

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Author Contributions

Conceptualization: BR, OH; Methodology: BR, OH, AR; Formal analysis: BR, OH; Investigation: BR, AR; Writing – original draft: BR; Writing – review & editing: BR, OH, AR; Supervision: OH.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Use of Artificial Intelligence

The authors used artificial intelligence tools only to assist with language refinement and clarity. All AI-assisted suggestions were carefully reviewed and verified by the authors, who take full responsibility for the accuracy, originality, and final content of the manuscript.

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