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Enhancing students' self-directed learning and achievement through an integrated probing-prompting and inside outside circle model

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ABSTRACT

Self-directed learning is an essential competency for elementary students as it strongly influences their academic success. However, observations at SDN Leuwinutug 4 indicate that students' learning independence and mathematics achievement remain below expectations. Prior research has examined the Probing-Prompting model and the Inside Outside Circle (IOC) strategy separately, but limited studies have explored their combined potential to strengthen students' autonomy and learning outcomes. This study aims to analyze the effectiveness of an integrated Probing-Prompting and IOC model in improving students' self-directed learning and mathematics achievement. Employing a quasi-experimental design with a pretest–posttest control group, data were collected from 31 fifth-grade students using questionnaires and mathematics tests. Statistical analyses included normality testing, N-Gain, independent t-test, and Two-Way ANOVA. The results demonstrate significant improvements in both self-directed learning and learning achievement among students taught using the combined model compared with those receiving conventional instruction ($p < 0.05$). These findings indicate that integrating Probing-Prompting with IOC provides a synergistic instructional approach that effectively enhances student independence and academic performance. The study recommends broader application of this hybrid model to support active, autonomous, and collaborative learning environments in elementary mathematics classrooms.

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INTRODUCTION

Self-directed learning has increasingly become a central competency in contemporary education, particularly at the elementary level where foundational academic behaviors and autonomous learning habits begin to develop (Munifah et al, 2019a; Sumarni et al, 2019a; Sumarni et al, 2019b; Huda et al, 2019). Students who possess the ability to diagnose their learning needs, formulate goals, choose appropriate strategies, and evaluate their progress tend to achieve stronger academic outcomes and demonstrate higher learning resilience (Fajriyah et al., 2019; Gusnita et al., 2021; Firdaus et al., 2021; Man et al., 2023; Rezkiyana et al., 2024). However, classroom environments in many elementary schools remain predominantly teacher-centered, limiting opportunities for students to build autonomy, initiative, and metacognitive awareness (Yasin et al, 2020; Sunyono et al, 2022). Such limited engagement often leads to passive learning behaviors, reduced motivation, and weaker conceptual understanding, particularly in mathematics (Gusnita et al., 2021; Lorenza, 2021; Saputri et al., 2021; Nurjannah et al., 2022; Hisbullah et al., 2024).

Observations conducted at SDN Leuwinutug 4 further confirm these issues. Students frequently rely on peers to complete tasks, display minimal initiative when engaging with mathematical concepts, and show low enthusiasm in classroom participation. These behavioral patterns correspond with low mathematics achievement, with many students performing below the Minimum Mastery Criteria (KKM). This condition aligns with previous findings that passive pedagogical environments contribute significantly to reduced independence and lower learning outcomes (Lorenza, 2021; Azmi, 2015; Saputri et al., 2021; Nurjannah et al., 2022; Siti Norhalija et al., 2023). Hence, there is an urgent need to implement instructional approaches that enhance student autonomy while simultaneously strengthening conceptual understanding.

Among the instructional models identified as promising solutions are Probing–Prompting and the Inside Outside Circle (IOC) cooperative learning technique. The Probing–Prompting model promotes deeper reasoning and conceptual understanding through sequential questioning that activates prior knowledge and supports cognitive construction processes (Abidin, 2017; Muthmainnah et al., 2019; Sutrisno & Suyitno, 2018; Hasil et al., 2014; Nurrita, 2018). Meanwhile, IOC encourages structured peer interaction, communication, and cooperative problem-solving, consistent with Vygotsky's sociocultural theory, which highlights the central role of social interaction in the development of higher-order thinking (Azmi, 2015; Lorenza, 2021; Saputri et al., 2021; Nurjannah et al., 2022; Gusnita et al., 2021). Although both models have individually demonstrated their effectiveness, empirical studies exploring their combined potential remain limited.

A comprehensive review of existing literature reveals several significant research gaps. First, few studies have attempted to integrate Probing–Prompting and IOC into a unified hybrid instructional model (Diani et al, 2019; Munifah et al, 2019b; Huda et al, 2020a; Huda et al, 2020b), despite the complementary nature of inquiry-oriented questioning and cooperative peer engagement (Abidin, 2017; Azmi, 2015; Muthmainnah et al., 2019; Lorenza, 2021; Saputri et al., 2021). Most previous research has examined each model in isolation, missing the potential synergistic effect that may arise when cognitive scaffolding is paired with social collaboration. Second, limited research has investigated how these instructional models influence self-directed learning a construct recognized as highly influential in shaping students' mathematical reasoning and academic achievement (Fajriyah et al., 2019; Gusnita et al., 2021; Firdaus et al., 2021; Siti Norhalija et al., 2023; Rezkiyana et al., 2024). Third, empirical studies focusing on the application of these integrated models in elementary mathematics contexts remain scarce, despite the critical role of this stage in fostering early independence and foundational mathematical literacy (Lorenza, 2021; Azmi, 2015; Nurjannah et al., 2022; Saputri et al., 2021; Man et al., 2023).

Addressing these gaps, the present study examines the effectiveness of a hybrid instructional approach that combines Probing–Prompting with the Inside Outside Circle technique. This integrated model is expected to foster a more active, collaborative, and metacognitively enriching learning environment that enhances both self-directed learning and mathematics achievement. More specifically, the study aims to evaluate improvements in students' learning independence and academic performance, as well as to analyze the relationship between these variables within the context of inquiry-driven and cooperative instruction. Through this contribution, the study offers new empirical evidence supporting innovative instructional designs that promote autonomy, engagement, and improved learning effectiveness in elementary mathematics education.

METHOD

This study employed a quasi-experimental design with a quantitative approach, using a *pretest–posttest non-equivalent control group design*. Two groups were involved: an experimental group that received the hybrid Probing–Prompting and Inside Outside Circle (IOC) model, and a control group that received conventional instruction. This design was selected because random assignment was not feasible, while still allowing comparison of learning gains and self-directed learning between groups.

The research design used in this study is illustrated as Figure 1.

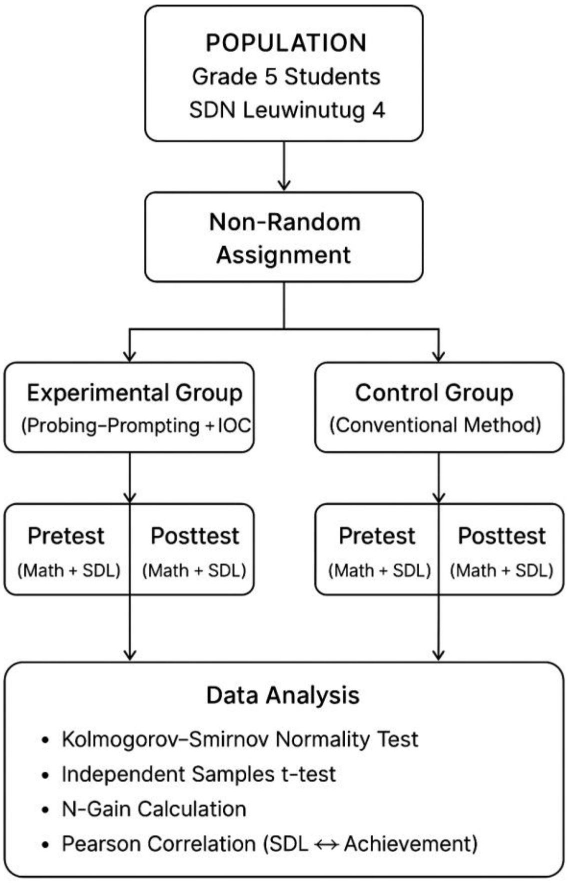

Figure 1. Research Design

The sample consisted of 31 fifth-grade students at SDN Leuwinutug 4, Kabupaten Bogor. Self-directed learning data were obtained through a validated questionnaire, while mathematics achievement was measured using pretest and posttest assessments aligned with curriculum indicators. All instruments were validated by experts and tested for reliability.

Data analysis was conducted in several stages. First, the Kolmogorov–Smirnov test was applied to examine normality. After meeting parametric assumptions, an independent samples t-test was used to examine differences in achievement. N-Gain scores were calculated to measure improvement using the standard Hake (1998) formula:

$$N - Gain = \frac{Posttest - Pretest}{Maks\ Score - Pretest}$$

$$g = \frac{X_{\text{post}} - X_{\text{pre}}}{X_{\max} - X_{\text{pre}}}$$

N-Gain was categorized as: high ($g > 0.70$), medium ($0.30 \leq g \leq 0.70$), and low ($g < 0.30$).

To analyze the relationship between self-directed learning and mathematics achievement, Pearson's correlation coefficient was applied. All analyses were conducted at a significance level of α = 0.05.

RESULTS AND DISCUSSION

The analysis began by evaluating the descriptive statistics of the pretest and posttest scores from both the control and experimental groups. As shown in **Table 1**, the experimental class—taught using the hybrid Probing–Prompting and Inside Outside Circle (IOC) model—demonstrated substantially higher improvement than the control class, which received conventional instruction. The experimental group reached a posttest mean of 49.23, far exceeding the control group's 30.42. This pattern is reinforced across other indicators such as median, range, variance, and standard deviation, suggesting that the hybrid model not only increased average performance but also expanded the distribution of learning gains. These results align with earlier findings that inquiry-based and cooperative strategies enhance conceptual understanding and student engagement (Abidin, 2017; Muthmainnah et al., 2019; Saputri et al., 2021).

Table 1. Descriptive Statistics (Control vs Experimental Group)

	Control		Experimen		Gain	
	Pretest	Postest	Pretest	Postest	Pretest	Postest
Mean	13.68	30.42	14.04	49.23	19.57	41.24
Median	6	33	9.5	38	21.28	34.36
Modus	0	6	6	26	6	0
Max	33	66	40	100	53	100
Min	0	66	0	13	-35.14	-6.67
Range	33	101.14	40	87	88.14	106.67
Varians	160.34	449.37	168.92	766.10	506.65	994.93
SD	12.66	21.20	13	27.68	22.51	31.54

Before conducting inferential tests, the normality of the data was examined using the Kolmogorov–Smirnov test. All p-values exceeded α = 0.05, as shown in **Table 2**, indicating that all datasets (pretest, posttest, and N-Gain) were normally distributed. This ensures that subsequent parametric analyses were applied appropriately and reliably.

Table 2. Kolmogorov–Smirnov Normality Test

	Kontrol		Eksperimen		N-Gain	
	Pretest	Postest	Pretest	Pretest	Postest	Pretest
p-value	0.05867	0.12783	0.32903	0.39697	0.44139	0.95108
α	0.05	0.05	0.05	0.05	0.05	0.05
Conclusion	Normal	Normal	Normal	Normal	Normal	Normal

The independent samples t-test provided additional insight into group differences. As shown in **Table 3**, the pretest scores between the control and experimental groups did not differ significantly (p = 0.433), confirming that both groups started with comparable baseline knowledge. However, the posttest revealed a statistically significant difference (p = 0.027), with the experimental group outperforming the control group. N-Gain scores also showed a meaningful difference (p = 0.015), suggesting that the hybrid instructional model led to significantly greater improvement in student learning. These results are consistent with existing research indicating that combining guided inquiry with structured collaborative learning enhances students' mathematical reasoning and problem-solving skills (Nurjannah et al., 2022; Lorenza, 2021).

Table 3. Independent Samples t-test Results

	Pretest	**Postest**	**N-Gain**
p-value	0.433	0.027	0.015
α	0.05	0.05	0.05
Conclusion	Not Any Different	Any Different	Any Different

Self-directed learning (SDL) was categorized using Sturges' rule. The experimental class had a higher proportion of students in the medium and high SDL categories, while the control class had more students in the lower category (Tables 4 and 5). This pattern suggests that the hybrid learning model effectively supported the development of autonomy, initiative, and reflective learning—key dimensions of SDL (Fajriyah et al., 2019; Gusnita et al., 2021).

Table 4. Grouping of Experimental Class Data

Sturgess's rule	
High	68-100
Medium	37-67
Low	6-36

Table 5. Grouping of Experimental Class Data

Sturgess's rule	
High	44-66
Medium	22-43
Low	0-21

To further examine how self-directed learning levels and instructional methods influenced achievement, a Two-Way ANOVA was conducted. The results in **Table 6** show significant effects for SDL level (Factor A), instructional method (Factor B), and their interaction (AB). This interaction indicates that the effectiveness of the hybrid model varies by students' SDL level, with those demonstrating higher autonomy benefiting the most. This result adds depth to current understanding by showing that instructional models do not operate in isolation, but interact dynamically with learner characteristics.

Table 6. Two-Way ANOVA Test Results

Source	Degree of Freedom (Df)	Sum of Square (SS)	Mean Square (MS)	F statistic (df1,df2)	p-value
Factor A – rows (A)	2	23555.3616	11777.6808	184. 3469 (2,40)	0
Factor B – columns (B)	1	3302.5504	3302.5504	51.6923 (1,40)	1.022e-8
Interaction AB	2	2939.0187	1465.0093	22.9307	2.319e-7

				(2,40)	
Error	40	2555.5476	63.8887		
Total	45	32343.4783	718.744		

Beyond confirming the effectiveness of the hybrid model, this study also presents several new findings. First, it provides empirical evidence that integrating inquiry-driven questioning with structured cooperative learning simultaneously improves both mathematics achievement and self-directed learning two domains that prior studies have rarely examined together in an elementary context. Second, the significant interaction effect found in the Two-Way ANOVA shows that the hybrid model yields stronger benefits for students with higher initial SDL levels, revealing a synergistic mechanism between autonomy and collaborative inquiry. Third, the magnitude of N-Gain improvement exceeds that reported in studies using single-method instructional approaches, suggesting that the hybrid model produces multiplicative, rather than additive, learning effects. Fourth, the finding that SDL can be effectively strengthened in elementary school challenges the assumption that autonomy develops primarily in higher grades, offering new theoretical insight that instructional design can actively stimulate SDL development at earlier ages. Finally, the successful implementation of the hybrid model in real classroom conditions demonstrates its practicality and scalability, offering valuable guidance for teachers aiming to improve both cognitive and metacognitive learning outcomes (Ridwanulloh et al, 2022; Bumi et al, 2025: Usman et al, 2025).

Collectively, these findings deepen existing theoretical perspectives by showing that effective mathematics learning occurs when students are actively constructing knowledge through reflective questioning, dialogic interaction, and structured collaboration. The hybrid Probing–Prompting + IOC model thus emerges as a powerful instructional approach capable of enhancing both academic achievement and learner autonomy in elementary mathematics education.

Figure 2. Implementation of learning in the experimental class

CONCLUSIONS AND SUGGESTIONS

This study concludes that the hybrid Probing–Prompting and Inside Outside Circle (IOC) instructional model effectively enhances both mathematics achievement and self-directed learning among elementary school students. The experimental group showed significantly higher posttest scores and N-Gain values compared to the control group, indicating stronger conceptual understanding and learning improvement. In addition, students' levels of learning independence demonstrated a significant interaction with the instructional model, where those with higher self-directed learning benefited more from the hybrid approach. Overall, the findings demonstrate that combining inquiry-based questioning with structured cooperative interaction creates a learning environment that simultaneously strengthens cognitive performance and metacognitive development.

Teachers are encouraged to integrate the hybrid Probing–Prompting and IOC model into mathematics instruction to promote active engagement, reflective thinking, and student autonomy. Schools should provide adequate support through professional development and teaching resources to ensure successful implementation. Future researchers may explore the application of this hybrid model in other subjects or educational levels, as well as examine long-term impacts on student learning behaviors and metacognitive growth.

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AUTHOR CONTRIBUTIONS

The authors contributed equally to the formulation of the research concept, data collection, data analysis, manuscript writing, and approval of the final manuscript for publication.

CONFLICT OF INTEREST

The authors declare that there are no potential conflicts of interest related to the research, writing, or publication of this article.

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