Research Article

The Role of Thinking-in-Action Pedagogy in Enhancing Scientific Inquiry and Conceptual Understanding in Integrated Science

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Abstract: Developing students' scientific inquiry skills requires instructional approaches that make thinking explicit and connect conceptual knowledge with authentic practice. This action research examined the effectiveness of thinking-in-action pedagogy in fostering scientific inquiry and bridging theory and practice in Integrated Science instruction through the use of visible thinking routines. The study involved 60 Grade 7 students from Philippine Science High School-Western Visayas Campus during the 2022-2023 school year and employed a quasi-experimental pretest-posttest control group design with matched pairs based on prior academic performance. Results from a validated researcher-made instrument revealed no significant difference in pretest scores between the control and experimental groups, indicating comparable baseline understanding. However, posttest results showed a significant improvement in the experimental group exposed to thinking-in-action pedagogy. Students demonstrated enhanced conceptual understanding, problem-solving, reasoning, and reflective thinking skills, suggesting that making thinking visible supports deeper learning and effective integration of theory and practice. The findings provide evidence that integrating structured thinking routines in science instruction promotes active learning, critical thinking, and meaningful engagement, aligning with Sustainable Development Goal 4 (Quality Education).

Keywords: thinking-in-action; visible thinking routines; scientific inquiry; integrated science

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1. Introduction

The processes of thinking and learning are often perceived by learners as implicit, complex, and difficult to observe. Consequently, classroom practices frequently rely on tangible outputs – such as examinations and written assignments – as primary evidence of students' understanding and critical thinking. While this approach may appear efficient and familiar within traditional educational settings, it restricts educators' access to students' underlying cognitive processes. An exclusive focus on final products may obscure how students construct meaning, reason through problems, and develop conceptual understanding. In contrast, making students' thinking visible allows teachers to gather formative evidence of learning, thereby informing instructional decisions and enhancing teaching effectiveness (Ritchhart & Church, 2020).

In contemporary science education, there is a growing emphasis on cultivating students' scientific inquiry skills, critical thinking, and active engagement as core components of meaningful learning. Inquiry-based pedagogies have been consistently shown to improve students' conceptual understanding and higher-order thinking, particularly in science classrooms where learners are encouraged to ask questions, investigate phenomena, and interpret evidence (Arifin et al., 2025). However, despite this evidence, traditional instructional practices often continue to prioritize content transmission over cognitive engagement, resulting in limited opportunities for students to actively develop and refine inquiry skills. This instructional gap highlights the need for pedagogical approaches that explicitly support students' thinking processes during science learning.

Visible thinking routines are research-based strategies designed to make thinking explicit, scaffold cognitive processes, and enhance learning engagement. Project Zero at Harvard University has extensively investigated the use of thinking routines to guide students' thought processes and inspire reflective learning (Project Zero, 2024). These routines, including *Think-*

Pair-Share, What Makes You Say That?, and I Used to Think… Now I Think, provide structured frameworks that promote equitable participation, collaborative discussion, and metacognitive reflection (Guenther & Abbott, 2024; Li & Tu, 2024).

This action research investigates the role of thinking-in-action pedagogy in fostering scientific inquiry and improving learning outcomes among Grade 7 students in Integrated Science. Specifically, it examines whether the use of visible thinking routines can bridge the gap between theory and practice and support more meaningful science learning experience.

2. Materials and Methods

2.1. Research Design

This study adopted a quasi-experimental pretest–posttest control group design to examine the effectiveness of visible thinking routines in science instruction. The design involved two intact groups – an experimental group and a control group – without random assignment of individual participants. This approach is commonly used in educational research when random assignment is not feasible due to pre-existing class groupings and institutional constraints (Creswell & Creswell, 2023).

The design allowed for the comparison of students' academic performance before and after the intervention, as well as between groups, thereby enabling the assessment of changes attributable to the instructional strategy. The use of both pretest and posttest measures strengthened internal validity by controlling for baseline differences in prior knowledge and learning ability.

The intervention was implemented over a ten-month period, covering regular classroom instruction in Integrated Science. Both groups were taught the same learning competencies, followed the same curriculum standards, and were assessed using identical instruments. The key difference lay in the instructional approach: the experimental group received lessons embedded with visible thinking routines, while the control group was taught using conventional, teacher-centered instructional methods. Class-based group assignment ensured minimal disruption to the school's instructional schedule while maintaining ecological validity.

2.2. Participants

The participants of the study were 60 Grade 7 students enrolled at Philippine Science High School-Western Visayas Campus during the School Year 2022-2023. The school is a public science high school that admits academically gifted students, providing a relatively homogeneous academic context suitable for experimental comparison.

A purposive sampling technique was employed, consistent with recommendations for quasi-experimental studies conducted in natural educational settings (Creswell & Creswell, 2023). To minimize pre-existing differences between groups, a matched-subject design was utilized. Students were paired based on their average grades in Integrated Science from the previous academic quarter, which served as an indicator of prior academic performance.

Thirty matched pairs were formed and distributed equally between the experimental and control groups, ensuring baseline equivalence in terms of academic ability. Group assignment was done at the class level, maintaining intact classroom groupings. This matching procedure enhanced the comparability of the groups and reduced selection bias, thereby strengthening the internal validity of the study.

2.3. Data Collection

Data collection was conducted in three phases: pre-intervention, intervention, and post-intervention.

Prior to the implementation of the intervention, a 50-item pretest was administered to both groups to assess students' baseline knowledge and understanding of the targeted Integrated Science concepts. The test items were aligned with the prescribed curriculum standards and learning competencies.

During the intervention phase, the experimental group was exposed to five visible thinking routines integrated systematically into science instruction: *Think-Pair-Share, What Makes You Say That?, The Explanation Game, Give 3 Y's, and I Used to Think… Now I Think*. These routines were selected for their emphasis on reasoning, explanation, reflection, and metacognition. Instruction was delivered during regular class periods, ensuring that the intervention did not alter the allotted instructional time. The control group received instruction using conventional teaching methods, including lectures, textbook-based discussions, and standard classroom activities.

After the completion of the intervention, the same 50-item instrument was administered as a posttest to both groups to measure learning gains. Using identical pretest and posttest instruments allowed for direct comparison of students' performance and ensured consistency in measurement across time.

2.4. Data Analysis

Data were analyzed using both descriptive and inferential statistical techniques. Descriptive statistics, including means and standard deviations, were computed to summarize students' pretest and posttest performance in both groups. These statistics provided an overview of central tendency and variability in students' scores.

For inferential analysis, paired sample t-tests were employed to determine whether there were statistically significant differences between pretest and posttest scores within each group. This analysis assessed the extent of learning gains over time. Additionally, independent sample t-tests were conducted to compare the posttest scores of the experimental and control groups, thereby determining the effect of the visible thinking routines relative to conventional instruction.

All statistical tests were conducted at a .05 level of significance. Prior to analysis, assumptions of normality and homogeneity of variance were examined to ensure the appropriateness of the statistical procedures. The results of these analyses were used to evaluate the effectiveness of visible thinking routines in improving students' learning outcomes in Integrated Science.

2.5. Ethical Considerations

Ethical protocols were strictly observed throughout the study. Approval to conduct the research was obtained from the Campus Director and the Curriculum Division Chief of Philippine Science High School-Western Visayas Campus. Information sheets and informed consent forms were distributed to students and their parents or guardians prior to participation.

Participation was voluntary, confidentiality of data was ensured, and all collected data were used solely for research purposes. Upon completion of the study, results were disseminated to students, parents, and school administrators. Participants were formally acknowledged for their cooperation and contribution to the research.

3. Results

This section presents the statistical analysis of students' performance in Integrated Science before and after exposure to the thinking-in-action pedagogy. Independent-samples and paired-samples *t*-tests were employed to examine baseline equivalence between the control and experimental groups, compare post-intervention performance, and determine within-group learning gains attributable to the intervention. Effect sizes and confidence intervals were reported to assess the magnitude and educational significance of observed differences. The results provide empirical evidence on the impact of making students' thinking visible through structured instructional routines and establish the effectiveness of thinking-in-action pedagogy in enhancing conceptual understanding and overall academic performance in Integrated Science.

3.1. Level of Performance of Students in Integrated Science Before Exposure to Thinking in Action Pedagogy

This subsection examines the baseline performance of students in Integrated Science prior to the implementation of the thinking-in-action pedagogy. An independent-samples *t*-test was conducted to determine whether there were significant differences in pretest scores between the control and experimental groups, thereby establishing the comparability of the two groups before the intervention.

Table 1 presents the results of the independent-samples t-test indicate that there was no statistically significant difference in baseline performance in Integrated Science between the control and experimental groups prior to the implementation of the intervention, t (30) = 0.49, p = 0.63. Although the control group obtained a marginally higher mean score (M = 28.75, SD = 6.04) than the experimental group (M = 27.87, SD = 3.79), the mean difference of 0.88 points, with a 95% confidence interval ranging from 2.77 to 4.52, suggests that this variation was negligible. The small effect size (Cohen's d = 0.17) further supports the absence of meaningful differences in prior knowledge and skills between the two groups. These findings confirm that the participants began the study at a comparable level of conceptual understanding in Integrated Science, thereby strengthening the internal validity of the research

Table 1. Comparison of pretest performance in integrated science between control and experimental groups.

Pretest	M	SD	Mean difference	95% CI of the difference	t-value	df	p-value	Effect size (Cohen's d)
Control group (n=30)	28.75	6.04	0.88	2.77-4.52	0.49	30	0.63	0.17
Experimental group (n=30)	27.87	3.79						

Taken together, the absence of statistically significant differences in pretest scores indicates that the control and experimental groups were academically comparable prior to the intervention. This baseline equivalence suggests that both groups possessed similar levels of prior knowledge and skills in Integrated Science, providing a fair starting point for evaluating the effects of the thinking-in-action pedagogy. Establishing baseline equivalence allows post-intervention differences to be more confidently attributed to the thinking-in-action pedagogy rather than to pre-existing academic differences.

3.2. Level of Performance of Students in Integrated Science After Exposure to Thinking in Action Pedagogy

This subsection presents the post-intervention performance of students in Integrated Science and examines the effect of the thinking-in-action pedagogy. An independent-samples t-test was used to compare the posttest scores of the control and experimental groups to determine whether the intervention led to significant differences in learning outcomes.

Table 2 presents the comparison of post-intervention performance in Integrated Science between the control and experimental groups. Results of the independent-samples *t*-test revealed a statistically significant difference in favor of the experimental group, $t\,(30) = 4.98$, $p < .001$. Students exposed to thinking-in-action pedagogy obtained substantially higher posttest scores ($M = 40.75$, $SD = 2.20$) than those in the control group ($M = 34.56$, $SD = 4.45$). The mean difference of 6.19 points, with a 95% confidence interval ranging from 3.65 to 8.73, indicates a meaningful improvement in learning outcomes attributable to the intervention. Moreover, the large effect size (Cohen's $d = 1.76$) suggests that the observed difference is not only statistically significant but also educationally substantial. These findings provide strong empirical support for the effectiveness of thinking-in-action pedagogy in enhancing students' conceptual understanding, reasoning, and overall performance in Integrated science instruction.

Table 2. Comparison of post-intervention performance in integrated science between control and experimental groups.

Posttest	M	SD	Mean difference	95% CI of the difference	t-value	df	p-value	Effect size (Cohen's d)
Control group (n=30)	34.56	4.45	6.19	3.65-8.73	4.98	30	<.001	1.76
Experimental group (n=30)	40.75	2.20						

These results demonstrate that the integration of thinking-in-action pedagogy had a substantial positive impact on students' learning in Integrated Science. The significantly higher posttest performance of the experimental group suggests that instructional approaches emphasizing active thinking, visible reasoning, and student engagement are more effective than traditional methods in promoting deeper understanding of scientific concepts. The large effect size further indicates that the observed gains are educationally meaningful and likely to have practical implications for classroom instruction. Thus, thinking-in-action pedagogy appears to be a powerful instructional strategy for improving students' conceptual mastery and cognitive engagement in Integrated Science.

3.3. Comparison of Pretest and Posttest Scores of the Experimental Group in Integrated Science

This subsection analyzes the within-group changes in performance of students exposed to the thinking-in-action pedagogy. A paired-samples *t*-test was conducted to compare the pretest and posttest scores of the experimental group and to assess the magnitude of learning gains attributable to the intervention.

Table 3 presents the results of a paired-sample t-test conducted to determine the effect of thinking-in-action pedagogy on the performance of students in the experimental group. The analysis revealed a highly significant increase in students' Integrated Science scores from the pretest (M = 27.87, SD = 3.79) to the posttest (M = 40.75, SD = 2.20), t (15) = 13.90, p < .001. The mean gain of 12.88 points, with a 95% confidence interval ranging from 10.90 to 14.85, indicates a substantial improvement in learning outcomes following the intervention. The effect size was extremely large (Cohen's d = 3.48), demonstrating the strong and meaningful impact of thinking-in-action pedagogy on students' conceptual understanding. These results suggest that making students' thinking visible through structured routines significantly enhances learning in Integrated Science and supports deeper, more reflective engagement with scientific concepts.

Table 3. The difference in the level of performance in integrated science of the experimental group before and after the intervention.

Test	M	SD	Mean difference	95% CI of the difference	t-value	df	p-value	Effect size (Cohen's d)
Pretest	27.87	3.79						
Posttest	40.75	2.20	12.88	10-90-14.85	13.90	15	<.001	3.48

The significant learning gains observed among students exposed to the thinking-in-action pedagogy are consistent with recent literature highlighting the role of metacognitive and constructivist instructional approaches in science education. Studies published in the last few years indicate that instructional practices which prompt learners to articulate reasoning, justify claims with evidence, and reflect on conceptual change significantly enhance conceptual understanding and academic performance (Dignath & Veenman, 2021; Schraw et al., 2006). In particular, visible thinking routines have been shown to promote metacognitive awareness by making students' cognitive processes explicit, thereby supporting self-regulation and deeper engagement with scientific concepts (Ritchhart, 2020). Recent empirical findings further suggest that sustained integration of metacognitive questioning and reflective activities in science classrooms leads to meaningful improvements in achievement and higher-order thinking skills (Zohar & Barzilai, 2022). Taken together, these contemporary studies support the present findings and reinforce the effectiveness of thinking-in-action pedagogy as a powerful approach for fostering deep and durable learning in secondary science education.

4. Discussion

The results of the study demonstrate that both groups began the intervention with comparable levels of conceptual understanding, ensuring that subsequent differences in performance could be attributed to the thinking-in-action pedagogy rather than pre-existing disparities. Establishing this baseline equivalence strengthens the internal validity of the study and provides a fair and reliable foundation for evaluating the impact of the intervention.

The findings also highlight the transformative potential of thinking-in-action pedagogy in the science classroom. Students who engaged with visible thinking routines demonstrated not only deeper conceptual understanding but also enhanced problem-solving, reasoning, and metacognitive skills. The substantial gains in performance suggest that guiding students to make their thinking visible and encouraging reflection on their thought processes effectively bridges the gap between theory and practice, resulting in learning that is both more meaningful and motivating.

Research indicates that visible thinking routines act as scaffolded cognitive tools, helping learners visualize, articulate, and organize their thinking while fostering engagement and reflective learning (Project Zero, 2024; The University of Chicago Center for Teaching and Learning, 2025). Structured routines such as *Think-Pair-Share* and other visible thinking strategies have been shown to promote equitable participation, richer classroom discussions, and deeper cognitive engagement, enabling students to express and justify their ideas with clarity and confidence (Guenther & Abbott, 2024; Li & Tu, 2024). Furthermore, these routines enhance student engagement, organization of ideas, and active processing of content, making learning more interactive and student-centered (Gholam, 2024; Ramos-Vallecillo et al., 2024). They also support metacognitive development, allowing learners to monitor and reflect on their thinking which is an essential component for sustained inquiry and deeper understanding of scientific concepts (Project Zero, 2025; Jarbulova & Abdezimova, 2025).

The findings of this study provide compelling evidence that the implementation of thinking-in-action pedagogy and visible thinking routines in science education can substantially enhance academic performance, cognitive engagement, and reflective learning. By actively guiding students to articulate, examine, and refine their thinking, educators can transform science learning into an experience that is not only more effective but also personally meaningful, intrinsically motivating, and closely aligned with authentic scientific inquiry. Such approaches empower students to connect theory with practice, develop critical thinking skills, and engage deeply in the processes of reasoning, problem-solving, and self-reflection, fostering a classroom culture centered on active, thoughtful, and reflective learners.

Moreover, these outcomes directly support Sustainable Development Goal 4 (SDG 4: Quality Education), which aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all (United Nations, 2023). By cultivating critical thinking, metacognition, and engagement through visible thinking routines, educators contribute to building competent, creative, and reflective learners who are better prepared to participate in knowledge-based societies and address global challenges. This alignment highlights how research-based pedagogical strategies in science education not only enhance academic outcomes but also advance broader educational and societal goals.

5. Conclusions

This study provides compelling evidence that the integration of thinking-in-action pedagogy through visible thinking routines significantly enhances students' academic performance, cognitive engagement, and reflective learning in Integrated Science. Students who experienced the intervention demonstrated notable gains in conceptual understanding, reasoning, problem-solving, and metacognitive skills, underscoring the instructional value of making learners' thinking explicit and systematically guided.

The use of structured routines such as *Think-Pair-Share, What Makes You Say That?, and I Used to Think… Now I Think* fostered active participation, equitable classroom discourse, and sustained cognitive engagement. These routines encouraged students to articulate ideas, examine evidence, and reflect on conceptual change, thereby cultivating a classroom culture that prioritizes thinking, understanding, and meaningful learning. The findings highlight how deliberate instructional design can transform science classrooms from content-delivery spaces into environments that promote inquiry, reflection, and deeper learning.

Beyond academic outcomes, the results suggest that thinking-in-action pedagogy supports the development of reflective, motivated, and engaged learners. By bridging theory and classroom practice, visible thinking routines empower students to take ownership of their learning and develop transferable skills essential for scientific inquiry and lifelong learning. The sustained implementation of these routines demonstrates their potential as core instructional practices rather than supplementary strategies.

From a broader perspective, this study contributes empirical support for learner-centered and cognitively rich pedagogical approaches in science education. Educators are encouraged to integrate visible thinking routines into regular instruction to promote critical thinking, deepen conceptual understanding, and create inclusive learning environments that value students' voices and thought processes. Future research may explore the long-term impact of thinking-in-action pedagogy across different subject areas and educational contexts.

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Informed Consent Statement: Prior to the conduct of the study, students were informed of the purpose and procedures of the research through an orientation. Parents or guardians were formally notified through written communication outlining the study schedule and its potential benefits. Written consent and necessary permissions were obtained from all concerned parties. The study was conducted in accordance with established ethical standards for research in-volving human participants.

Conflicts of Interest: The author declares no conflict of interest.

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