JIPSINDO (Jurnal Pendidikan Ilmu Pengetahuan Indonesia)
ISSN: 2355-0139 (p); 2615-7594 (e)
Vol. 13. No. 1 (2026), pp. 1-13 , DOI: https://doi.org/10.21831/jipsindo.v13i1.89223

Application of Neuroscience Principles in a Problem-Based Learning (PBL) Model Integrated with the Tamansiswa Educational Philosophy to Enhance Fifth-Grade Students' Learning Engagement

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Article History
Submitted: 8 September 2025
Revised: 23 September 2025
Accepted: 24 September 2025

Keywords:

Neuroscience, Problem Based Learning, Tamansiswa, learning activeness.

Abstract

Student engagement is widely recognized as a key determinant of meaningful learning and long-term academic development in primary education. However, sustaining active participation remains a challenge in many classrooms. This study investigates the effectiveness of integrating neuroscience-informed learning principles into a Problem-Based Learning (PBL) model aligned with the Tamansiswa educational philosophy to enhance learning engagement among fifth-grade students. The research employed a classroom-based intervention design with iterative instructional refinement implemented in a Grade V class at SD Negeri 1 Depok, Kulon Progo, Yogyakarta, Indonesia. The instructional design incorporated neuroscience-informed strategies, including attention priming, emotionally supportive classroom norms, generative processing, retrieval practice, and structured metacognitive reflection within the stages of PBL. Data were collected through structured classroom observations, student reflections, and documentation of learning activities, focusing on behavioral, cognitive, and emotional dimensions of engagement. Quantitative results indicate that the mean engagement score increased from 55.22% during the initial implementation phase to 77.20% after instructional refinement, surpassing the predetermined success criterion of 75%. The normalized gain score ($g = 0.49$) suggests a moderate improvement in student engagement. Qualitative findings further reveal more balanced group participation, increased student questioning, and deeper reflective responses during learning activities. The findings suggest that integrating neuroscience-informed instructional strategies with problem-based pedagogy and culturally grounded educational philosophy can effectively foster active participation and collaborative learning in primary classrooms. This study contributes to the growing field of neuroeducation by demonstrating how neuroscience principles can be operationalized within culturally responsive instructional design to support student engagement.

Introduction

Student engagement at the primary level has been widely recognized as a critical determinant of meaningful learning, socio-emotional development, and long-term academic success. Engagement reflects the degree to which students are behaviorally involved, cognitively invested, and emotionally connected to learning activities (Fredricks et al., 2004; Wijnia et al., 2024).. From a neuro educational standpoint, these gains are plausibly mediated by mechanisms of attention, working memory, consolidation, and emotion regulation that are more robustly recruited when learners generate and apply ideas rather than merely receive them (Dubinsky & Hamid, 2024; Pradeep et al., 2024). When students are actively engaged, they are more likely to sustain attention, regulate their learning processes, and construct deeper conceptual understanding. Conversely, low engagement often leads to superficial learning, reduced motivation, and limited knowledge transfer. Consequently, contemporary educational research increasingly emphasizes the design of learning environments that promote active participation, inquiry, and collaborative knowledge construction.

A growing body of empirical evidence suggests that classrooms structured around active learning—where students are encouraged to question, discuss, and publicly articulate their reasoning—consistently produce stronger learning outcomes compared to classrooms dominated by passive instruction (Freeman et al., 2014; Grijpma et al., 2024). Active learning approaches enable learners to generate ideas, test hypotheses, and refine understanding through interaction with peers and teachers. These processes not only foster deeper conceptual comprehension but also enhance motivation and self-regulated learning skills.

From a neuroeducation perspective, the effectiveness of active learning can be explained through several cognitive and neural mechanisms. Neuroscience research indicates that learning is optimized when instructional activities stimulate attention, working memory, emotional engagement, and long-term memory consolidation (Howard-Jones, 2014; Dubinsky & Hamid, 2024). When students actively construct and apply knowledge, neural networks associated with executive function, reward processing, and memory formation are more strongly activated. Such engagement facilitates generative processing, retrieval practice, and the strengthening of synaptic connections that underpin durable learning (Agarwal et al., 2021; Trumble et al., 2024). In contrast, passive reception of information tends to involve lower cognitive activation and limited retention. Therefore, integrating neuroscience-informed principles into instructional design has become an important strategy for improving learning effectiveness.

In Indonesian primary schools, thematic learning often aims to cultivate inquiry and character simultaneously, yet many classrooms still report uneven levels of active participation. A pedagogical design that explicitly couples neuroscience-informed principles with Problem-Based Learning (PBL)—and is aligned with local educational philosophy—may provide a coherent route to strengthen engagement and agency in Grade V classrooms (Ningrum et al., 2021; Ferary, 2021; Zulfiati et al., 2019).

Recent synthesis work in cognitive neuroscience explains how active learning outperforms direct instruction: by increasing selective attention to task goals, reducing extraneous load through emotionally safe climates, deepening elaboration via generative processing, and enhancing consolidation/transfer through retrieval and spaced practice (Dubinsky & Hamid, 2024; Trumble et al., 2024; Agarwal et al., 2021). Importantly, these mechanisms operate in concert during well-structured, learner-centered activities. Neuroeducation reviews likewise highlight the bidirectional alignment between neural dynamics (e.g., executive control, reward/motivation circuits) and pedagogical strategies that require students to plan, monitor, explain, and revise their thinking (Pradeep et al., 2024).

PBL inherently organizes instruction around authentic problems, small-group collaboration, and public explanation of solutions. A 2024 meta-analysis across problem-driven approaches (PBL/PjBL/CBL) found small-to-moderate positive effects on student motivation—spanning competence beliefs, task value, and reasons for engagement—when implementations are well facilitated (Wijnia et al., 2024). Complementary studies in small-group active learning show that expert teacher facilitation (e.g., prompting, role rotation, and timely feedback) is pivotal for sustaining behavioral, cognitive, and emotional engagement during collaborative problem solving (Grijpma et al., 2024).

Beyond pedagogical effectiveness, educational innovation in Indonesia must also consider cultural and philosophical foundations of learning. The Tamansiswa educational philosophy introduced by Ki Hadjar Dewantara emphasizes the holistic development of learners through guidance, independence, and social responsibility. Dewantara's well-known principle "*ing ngarso sung tulodho, ing madya mangun karso, tut wuri handayani*" positions the teacher as a role model in front, a motivator among learners, and a supporter who empowers students from behind. Central to this philosophy is the concept of *among*, which emphasizes nurturing students' freedom and creativity while guiding them toward responsible participation in society (Ferary, 2021; Rohman, 2021). This philosophical perspective aligns closely with contemporary learner-centered pedagogies that view teachers as facilitators who support students' autonomy and active participation in learning processes. Despite converging evidence for (a) neurocognitive mechanisms supporting active learning and (b) the motivational benefits of problem-driven pedagogies, there is limited classroom-level research that explicitly operationalizes neuroscience principles within a PBL design and contextualizes facilitation using Tamansiswa values at the primary level.

This study addresses that gap by (i) articulating concrete, neuroscience-informed design moves (attention priming, emotionally safe norms, generative processing, retrieval/spaced reviews, structured metacognition) within each PBL phase, and (ii) mapping teacher roles to *among* principles to cultivate independence and responsibility appropriate to Grade V students (Ningrum et al., 2021; Dubinsky & Hamid, 2024). To support consistent enactment, we also draw on current TPACK syntheses that stress balanced integration of

ISSN: 2355-0139 (p); 2615-7594 (e)

technological, pedagogical, and content knowledge for high-fidelity, student-centered implementation (Schmid et al., 2024). By integrating insights from neuroscience, problem-based pedagogy, and Indonesian educational philosophy, this research seeks to contribute to the development of culturally grounded and cognitively informed learning models that can enhance student engagement in primary education.

Method

This study employed a classroom based intervention desin with iterative instructional refinement with purpose to enhance learning engagement of fifth grader during a thematic science unit. The instructional intervention integrated a Problem Based Learning (PBL) model with some neuroscience informed learning principle, including attention priming, emotionally safe norms, generative processing, brief retrieval checks, and structured metacognitive reflection. All instructional elements were incorporated to stimulate student's attention, cognitive process, and memory consolidation which are essential for effective learning while remaining consistent with the Tamansiswa philosophy of *among*, in which the teacher guides learners toward autonomy and responsibility (Agarwal et al., 2021; Ferary, 2021; Ningrum et al., 2021; Trumble et al, 2024). The intervention was implemented through two instructional phases, allowing reflective refinement of teaching strategies between phases. This iterative design is commonly used in classroom-based educational research to evaluate the effectiveness of instructional innovations while allowing adjustments based on classroom observations and student responses (Creswell & Creswell, 2018; McKenney & Reeves, 2019). The instructional design was aligned with Tamansiswa educational philosophy, particularly the concept of among, which emphasizes teacher's role in nurturing learner's independence, responsibility, and intrinsic motivation.

The study took place at SD Negeri 1 Depok, Panjatan District, Kulon Progo Regency, Special Region of Yogyakarta (postal code 55655), during the even semester of the 2021/2022 academic year. Implementation unfolded across four meetings: Cycle I on 14 and 19 April 2022, followed by Cycle II on 26 and 28 April 2022. The participants were an intact class of 26 Grade V students whose characteristics were heterogeneous, with both shy and highly talkative pupils present. Learning activities were therefore designed to distribute participation equitably within small groups and to provide structured roles so that every student contributed meaningfully to problem analysis and solution presentation (Grijpma et al., 2024).

The learning ectivities were organized following the stages of Problem Based learning design, which include problem orientation, collaborative investigation, solution development, and presentation of findings. Each lesson began with a short attention orienting activity designed to activate prior knowledge and

In the planning phase of each cycle, the research team prepared lesson plans (RPP), student worksheets (LKPD), and observational instruments aligned with the targeted engagement indicators. The action phase consisted of PBL lessons anchored to authentic problems familiar to the students' daily experiences. Lessons opened with brief attention-orienting prompts and affect-safe agreements to reduce extraneous load and encourage risk-free participation. Students then generated initial ideas, organized inquiry steps, and investigated with guidance, using multimodal resources to build explanations. Short retrieval checks were embedded to strengthen consolidation, and each meeting concluded with metacognitive reflection on strategies that helped or hindered progress (Agarwal et al., 2021; Trumble et al., 2024). "Learning activities were designed to distribute participation equitably within small groups and to provide structured roles so that every student contributed meaningfully (Grijpma et al., 2024; Suharno & Rohman, 2021). "Throughout, the teacher acted as a facilitator in line with *ing madya mangun karso*—scaffolding discussion, circulating among groups, and prompting clarification without dominating the inquiry (Ferary, 2021; Wijnia et al., 2024).

ISSN: 2355-0139 (p); 2615-7594 (e)

Data on student learning engagement were collected using structured classroom observation protocols and student activity documentation. The observation instrument focused on three dimensions of engagement commonly identified in educational research: behavioral engagement, cognitive engagement, and emotional engagement (Fredricks et al., 2004). Behavioral engagement indicators included participation in group discussions, contribution to problem-solving tasks, and attentiveness during instructional activities. Cognitive engagement was observed through students' efforts to analyze problems, generate explanations, and connect ideas during collaborative inquiry. Emotional engagement was reflected in students' enthusiasm, curiosity, and willingness to participate in classroom discussions.

Data were analyzed using descriptive comparative analysis to examine changes in student engagement across the instructional phases. Observational data were summarized using frequency distributions and descriptive statistics to identify patterns of participation and engagement throughout the learning process. To enhance credibility, findings were triangulated through multiple sources of evidence, including classroom observations, student learning artifacts, and reflective teaching notes. Triangulation is widely recommended in classroom-based research to strengthen the validity of interpretations and provide a comprehensive understanding of learning processes (Creswell & Creswell, 2018).

Result and Discussion

This section presents both quantitative and qualitative findings will be presented from the classroom based instructional implementation. The analysis aimed to evaluate whether the integration of neuroscience principles into the PBL model aligned with Tamansiswa's among philosophy—successfully enhanced students' learning engagement and achieved the ≥ 75% success criterion.

Quantitative results are presented first, showing the change in mean engagement scores between Cycle I and Cycle II, followed by qualitative findings that describe shifts in participation patterns, questioning behavior, and the depth of students' reflections.

Quantitative results are presented first to illustrate the change in mean engagement scores across the two instructional phases. These are followed by quantitative observation describing shifts in participation patterns, questioning behavior, and the depth of student's reflective responses during the learning process. Table 1 presents the percentage of student learning engagement observed during the two phases of the instructional implementation.

Table 1 presents the percentage of student learning engagement across two cycles.

Cycle	**Mean Engagement (%)**	**Category**
I	55.22	Moderately Active
II	77.20	Active

The results indicate a 21.98 percentage-point improvement from Cycle I to Cycle II, surpassing the success indicator. Qualitative observations showed richer classroom questioning, more equitable group participation, and more reflective exit tickets in Cycle II. Students appeared more confident in expressing opinions, and teacher field notes recorded fewer instances of off-task behavior. Note: The normalized gain (g) between Cycle I and Cycle II was calculated as 0.49, indicating a medium improvement in learning engagement (Hake, 1998).

Qualitative observations recorded not only more frequent participation but also richer contributions from students. Previously passive students began to raise questions and present ideas during group work, while dominant students became more balanced due to structured role rotation. Exit tickets in Cycle II showed more reflective answers, with students explicitly mentioning strategies that supported their understanding and confidence.

The improvement in learning engagement demonstrates that neuroscience-informed PBL effectively fosters active participation. Attention priming helped focus students' attention at the start of lessons, while psychologically safe participation norms created a classroom climate where students felt comfortable asking questions. Generative processing (idea generation) and retrieval practice (short in-lesson checks) contributed to stronger memory consolidation, consistent with the findings of Dubinsky & Hamid (2024) and Agarwal et al. (2021).

The observed improvements in engagement can be interpreted through several principles derived from neuroscience-informed learning research. From a neurocognitive standpoint, attention-priming activities at lesson openings helped focus students' attention on learning goals, consistent with Dubinsky & Hamid's (2024) model of goal-directed attentional control. The use of psychologically safe norms reduced performance anxiety and encouraged risk-taking, supporting emotional regulation mechanisms that sustain engagement. Generative processing during problem exploration deepened conceptual elaboration, while retrieval practice reinforced memory consolidation as reported by Agarwal et al. (2021)

Another important factor contributing to increased engagement was the teacher's facilitative role, which reflected the Tamansiswa principle of *among*. According to Ki Hadjar Dewantara's philosophy, effective teaching involves modeling appropriate learning behaviors, guiding students during collaborative inquiry, and empowering them to develop independence and responsibility (Ferary, 2021; Rohman, 2021).

During the intervention, the teacher functioned primarily as a learning facilitator, circulating among groups, prompting clarification, and encouraging students to articulate their reasoning. This role aligns with the Dewantaran principle of *ing madya mangun karso*, which emphasizes motivating learners from within the learning community rather than controlling the learning process from the front. These results are in line with Wijnia et al. (2024), who reported that well-facilitated PBL has a positive effect on motivation and engagement.

Triangulation of observations, student questionnaires, and documentation enhanced the validity of the findings. Although this study involved a single class and two cycles, the convergence of quantitative and qualitative data suggests that neuroscience-informed PBL can be replicated in similar settings with comparable outcomes.

Several practical insights emerged from the implementation of this instructional design. First, maintaining a structured lesson rhythm, consisting of orientation, exploration, investigation, retrieval, and reflection phases, can help sustain students' attention and engagement throughout the learning process. Secondly, a structured lesson rhythm: maintaining a consistent cycle of orient, explore, investigate, retrieve, and reflect can help sustain attention and engagement; third, the role rotation in group work to ensures equitable participation and reduces dominance by only a few students; and lastly, critical digital literacy: when AI-based learning assistants are used, teachers should guide students to use them as a support tool rather than a substitute for independent reasoning**.** These instructional design strategies are relatively low-cost and easily replicable, making them suitable for implementation within the Merdeka Curriculum framework. Furthermore, they may serve as useful examples for teacher professional development programs aimed at strengthening student engagement and promoting deeper learning in primary education.

Conclusion

This study examined the effectiveness of integrating neuroscience-informed learning principles into a Problem-Based Learning (PBL) model aligned with the Tamansiswa philosophy to enhance the learning engagement of fifth-grade students. Average engagement increased from 55.22% in Cycle I (moderately active) to 77.20% in Cycle II (active), meeting the ≥ 75% success criterion. Beyond quantitative gains, qualitative observations revealed richer classroom questioning, more balanced group participation, and deeper student reflections.

Mechanistically, the lesson architecture—attention priming, psychologically safe participation norms, generative processing, retrieval checks, and structured metacognitive reflection—activated neurocognitive pathways that sharpen attention, support working memory, and strengthen long-term consolidation. The teacher's facilitative stance, guided by Dewantara's principles (*ing ngarso sung tulodho, ing madya mangun karso, tut wuri handayani*), likely enhanced students' sense of agency and responsibility, sustaining collaborative momentum throughout the cycles.

This model is low-cost, feasible within existing timetables, and replicable for classroom teachers seeking to transform participation into deeper, more meaningful learning. Nevertheless, this study has several limitations. The research involved only one classroom and a relatively short implementation period, which may limit the generalizability of the findings. Future research could involve larger samples, longer implementation periods, and comparative designs to further examine the effectiveness of neuroscience-informed PBL models across different educational contexts. Overall, the results suggest that integrating neuroscience principles, problem-based pedagogy, and culturally rooted educational philosophy can provide a promising framework for enhancing student engagement and promoting deeper learning in primary education.

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