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Deep learning as an innovative solution to literacy and numeracy challenges in elementary schools

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ABSTRACT

Low literacy and numeracy achievement among Indonesian elementary school students remains a critical pedagogical challenge demanding systematic and contextual innovation. This study aims to analyze the implementation of the deep learning approach as an innovative solution to literacy and numeracy challenges. A qualitative methodology with a case study design was employed to enable in-depth exploration within real-life contexts. Participants consisted of one school principal, four teachers (Grades IV-VI), eight students, and three parents selected through purposive sampling. Data were collected through participatory observation, semi-structured in-depth interviews, and document analysis, and analyzed using Miles and Huberman's interactive model encompassing data reduction, data display, and iterative conclusion drawing. Trustworthiness was ensured through source and method triangulation alongside member checking. Findings reveal that the implementation of deep learning across three integrated stages mindful, meaningful, and joyful learning improved average literacy scores by 17 percentage points (from 62% to 79%) and numeracy by 16 percentage points (from 60% to 76%) over a three-month intervention period. Beyond quantitative gains, significant qualitative improvements were documented in student motivation, collaborative engagement, critical thinking, and academic self-confidence. Eighty-seven percent of teachers reported that this approach effectively facilitated the integration of digital technology in learning. This study concludes that deep learning constitutes a relevant, innovative, and replicable pedagogical strategy for addressing elementary-level literacy and numeracy challenges while simultaneously enhancing the quality of technology-integrated learning.

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INTRODUCTION

Basic education plays a fundamental role in shaping the intellectual, social, and emotional foundations of students as the nation's future generation (Aithal & Srinivasan, 2025; Rahmawati et al., 2025). Among the various competencies that must be mastered, literacy and numeracy are two key competencies that serve as prerequisites for student success at all levels of education.

Literacy encompasses not merely the ability to read and write, but also the ability to understand, interpret, evaluate, and use textual information in various life contexts (Nahak & Koroh, 2025). Meanwhile, numeracy refers to the ability to think mathematically in a logical manner and apply concepts of numbers, measurement, and simple statistics in real-world situations (Ibrahim et al., 2026; Verkerk et al., 2026). These two competencies form the foundation for the development of critical, creative, and analytical thinking, which are essential in the era of globalization and the Fourth Industrial Revolution.

Before proceeding, it is important to clarify that the term deep learning as used throughout this article refers exclusively to a pedagogical framework developed by Indonesia's Ministry of Education, Culture, Research, and Technology, encompassing mindful, meaningful, and joyful learning. It is entirely distinct from the computational concept of deep learning in artificial intelligence or machine learning (Janiesch et al., 2021). With this distinction established, the following section addresses the broader educational context motivating this study. Nationally, data from the Minimum Competency Assessment, which has been implemented by the Ministry of Education, Culture, Research, and Technology since 2021, indicates that the literacy and numeracy achievements of Indonesian elementary school students remain far from satisfactory (Purbaningrum et al., 2024; Setyaedhi, 2025). More than half of elementary school students have not yet reached the required minimum competency level, particularly in the dimensions of textual literacy and contextual numeracy (Grotlüschen et al., 2020). This situation is exacerbated by the dominance of conventional, teacher-centered learning methods, a lack of variety in learning media, minimal connection between lesson content and students' real-life contexts, and low intrinsic motivation among students (Mahat & Loh, 2024).

A similar situation was found at SD Negeri 11 Jangka, Aceh, Indonesia. A diagnostic assessment conducted in early 2024 on 30 students in grades 4-6 showed that the average literacy achievement was only 62% and numeracy 60%, with 40% of students falling into the low category for both. Initial observations also identified several learning barriers, including: (1) the dominance of lecture-based methods, which tend to make students passive; (2) the limited use of available digital media; (3) a lack of learning activities that connect the material to students' daily experiences; and (4) limited opportunities for students to collaborate and freely express their ideas. These conditions indicate the urgent need for innovative, student-centered, and contextual learning approaches.

In this context, the deep learning approach emerges as a promising pedagogical solution (Weng et al., 2023). It should be emphasized that deep learning in an educational context is entirely distinct from the concept of deep learning in artificial intelligence (machine learning) (Janiesch et al., 2021). In education, deep learning refers to the learning framework developed by the Ministry of Education, Culture, Research, and Technology (2023), which encompasses three main dimensions: (1) Mindful Learning-learning that is mindful, reflective, and purposeful; (2)

Meaningful Learning-learning that is meaningful, contextual, and connects concepts to real-life situations; and (3) Joyful Learning-learning that is enjoyable, creative, and fosters intrinsic enthusiasm for learning (Ahmad et al., 2021; Deng et al., 2024). These three dimensions Saputra et al. (2025) synergistically promote students' holistic engagement encompassing cognitive, affective, psychomotor, aesthetic, and ethical dimensions thereby fostering deeper and more enduring understanding (Sondarika et al., 2025).

A number of studies support the effectiveness of the deep learning approach in improving the quality of learning. The implementation of deep learning in elementary schools significantly improved students' reflective and applied thinking skills (Cahyanto, 2025; Sudarmono et al., 2025). The alignment of deep learning with constructivist theory, which underscores the importance of meaningful learning experiences (Correia et al., 2025). While prior studies have examined deep learning in broad educational settings (Wu, 2024) or explored its theoretical alignment with constructivism, they have not specifically investigated its simultaneous application across all three dimensions mindful, meaningful, and joyful learning as a unified intervention targeting both literacy and numeracy outcomes in under-resourced elementary schools. The present study addresses this gap by offering a contextually grounded empirical account from a peripheral school in Aceh, Indonesia, thereby contributing a replicable implementation model absent from the existing literature. Nevertheless, several research gaps remain to be addressed. First, studies exploring the contextual implementation of deep learning in elementary schools with limited resources in peripheral areas are still very scarce (Saputra et al., 2025; Subiyantoro & Musa, 2024). Second, there is little research specifically examining how the simultaneous integration of the three components mindful, meaningful, and joyful learning addresses literacy and numeracy challenges (Feriyanto & Anjariyah, 2024; Yazid Mubarok et al., 2024). Third, the perspectives of multiple stakeholders teachers, students, and parents regarding the process and impact of implementation have not been comprehensively documented (Çapar et al., 2026; Vanclooster et al., 2018).

Based on this background, this study was formulated with three specific objectives: (1) to map the current conditions and factors hindering literacy and numeracy achievement at SD Negeri 11 Jangka; (2) to describe the process of implementing the deep learning approach through the stages of mindful, meaningful, and joyful learning in classroom instruction; and (3) to analyze the impact of this implementation on improving literacy and numeracy achievement and the quality of learning holistically. Thus, this study is expected to provide strong empirical evidence and a replicable implementation model for the elementary education community in Indonesia.

To guide the inquiry, three research questions were formulated: (RQ1) What are the current conditions and key factors hindering literacy and numeracy achievement among Grade 4-6 students at SD Negeri 11 Jangka? (RQ2) How is the deep learning approach implemented through the integrated stages of mindful, meaningful, and joyful learning in classroom instruction at this

school? (RQ3) What is the impact of this deep learning implementation on students' literacy and numeracy achievement and on the holistic quality of learning, as perceived by teachers, students, and parents?

METHOD

Research Design and Approach

This study employs a qualitative approach using a case study design. The choice of this design is based on the characteristics of the research problem, namely the phenomenon of pedagogical implementation within a unique school context that cannot be separated from its real-world setting. A case study allows researchers to explore a specific system in depth through the collection of rich data from various sources, thereby yielding a holistic and contextual understanding of the phenomenon under investigation (Creswell & Creswell, 2017). A qualitative approach was chosen because the research objectives are oriented toward understanding meaning and processes rather than merely measuring outcomes and because the perspectives and experiences of the learning participants constitute the most relevant data for answering the research questions (Isik, 2025). It is important to clarify that, although this study is fundamentally qualitative in design, certain descriptive quantitative data (i.e., percentage scores from diagnostic and follow-up assessments) are incorporated as embedded supplementary statistics. These figures serve not as inferential measurements but as contextual descriptors that enrich the qualitative narrative and provide a transparent account of observable changes in student performance. This approach is consistent with qualitative case study practice, wherein numerical data may be used illustratively without altering the interpretive, meaning-oriented nature of the inquiry (Creswell & Creswell, 2017).

The research was conducted at SD Negeri 11 Jangka, Bireuen Regency, Aceh Province, from May to July 2025. The location was selected purposively based on two main considerations: (1) this school faces real challenges in literacy and numeracy achievement, as documented in internal assessments; and (2) this school has begun to implement a deep learning approach gradually, allowing the research to be conducted under authentic implementation conditions rather than in a simulated setting.

Research Participants

Research participants were selected using purposive sampling based on criteria of direct involvement and the relevance of their roles to the phenomenon under study. The number of participants was determined based on the principle of data saturation, which indicates that adding more informants would no longer yield substantial new information (Riswanto et al., 2023). Details of the participants are presented in Table 1. Regarding the specific selection criteria: the eight student participants were selected based on ability-level variation, comprising two students

from each performance category (high, satisfactory, and low) as determined by the initial diagnostic assessment, with two additional students selected on teacher recommendation due to notable learning difficulties. This stratified approach ensured that a range of learning experiences was captured. The three parent participants were selected on the basis of (a) being the primary caregiver of a participating student, and (b) willingness to participate. Parents of students from different performance levels were prioritized to reflect diverse home-learning contexts. In terms of demographic characteristics, participating students ranged in age from 10 to 12 years, with a gender distribution of five male and three female students. Participating parents had varying educational backgrounds (two had completed secondary education, one had completed primary education), a factor considered in interpreting reported changes in home learning support.

Table 1. Details of Research Participants

No.	Informant	n	Criteria and Role in the Research
1	School Principal	1	Instructional decision-maker; provides a strategic perspective on the direction of school learning innovation
2	Grades 4–6 Teachers	4	Direct implementers of the deep learning approach; provide data on the implementation process and evaluation of the impact on students
3	Grades 4–6 Students	8	Recipients of the learning intervention; provide perspectives on learning experiences and perceptions of change
4	Parents	3	Observers of learning development outside of school; provide data on changes in motivation and independence in learning at home
Total		**16**	

Data Collection Methods

Data were collected using three complementary primary methods. First, semi structured in-depth interviews were conducted individually with school principals and teachers, as well as in small-group formats with students. The interview guide was developed based on the dimensions of deep learning implementation and refined iteratively. Each interview session lasted between 45-90 minutes and was recorded with the informants' permission. Second, participatory observations were conducted by the researchers during 12 learning sessions in grades 4, 5, and 6, covering literacy, numeracy, and thematic learning sessions. The observation instrument was developed based on indicators of mindful, meaningful, and joyful learning, as well as indicators of student engagement. Third, document analysis was conducted on teaching modules (Lesson Plans), diagnostic and follow-up assessment results, student portfolios, teacher reflection notes, and school literacy-numeracy program evaluation reports.

Regarding the assessment instruments specifically, the literacy diagnostic instrument was developed based on the minimum competency assessment framework issued by the Ministry of Education, Culture, Research, and Technology, encompassing three core indicator domains: (1) reading comprehension of informational and literary texts; (2) text interpretation and inferencing; and (3) reflective and evaluative writing. The numeracy instrument likewise comprised three indicator domains: (1) contextual arithmetic and calculation; (2) understanding of number concepts, fractions, and ratios; and (3) mathematical problem-solving in real-world contexts. Both instruments were developed collaboratively by the research team and reviewed by two subject-matter experts (a literacy specialist and a mathematics education lecturer) to establish content validity. A readability pilot was conducted with five students not included in the main sample to ensure age-appropriate language and clarity. The follow-up (post-intervention) assessment employed a parallel-form instrument, constructed using the same indicator framework, to enable direct pre–post comparison while minimizing practice effects. While formal psychometric reliability testing (e.g., Cronbach's alpha) was not conducted consistent with the qualitative-dominant nature of this study the use of expert validation and parallel-form construction constitutes an appropriate level of instrument quality assurance for embedded descriptive assessment within a qualitative case study design.

Data Analysis Techniques

Data were analyzed using the interactive model proposed by Miles, Huberman, and Saldana, which consists of four components that occur simultaneously and iteratively. Data collection was conducted systematically and continuously throughout the study. Data reduction involved the process of selecting, focusing, and simplifying raw data by coding and categorizing it according to themes relevant to the research objectives. Data presentation was carried out in the form of descriptive narratives, thematic tables, and comparison matrices to facilitate the identification of patterns and relationships among categories. Drawing conclusions and verification are conducted in stages by confirming findings with data sources and performing in-depth interpretation (Miles et al., 2014).

Data validity is ensured through four strategies. Source triangulation is performed by comparing data from school principals, teachers, students, and parents to identify consistency or divergence in perspectives. Methodological triangulation is performed by comparing findings from interviews, observations, and documentation. Member checking is carried out by presenting the findings back to key informants to validate the accuracy of the researcher's interpretations. Specifically, a written summary of preliminary findings was shared with the school principal and all four teachers in a focused group discussion session held at the end of the third month of data collection. Students' parents were provided with brief verbal summaries during individual follow-up meetings. In total, five key informants participated in member checking. Minor clarifications

were made to two thematic interpretations following informant feedback, particularly regarding the categorization of parental involvement and the characterization of student self-confidence changes. An audit trail is maintained through the systematic documentation of all analysis procedures so that the research process can be traced and verified (Erdmann & Potthoff, 2023).

RESULTS

1. Overview of the School Context

SD Negeri 11 Jangka is a public elementary school located in Bireuen Regency, Aceh Province. The school serves 115 students from grades 1 through 6 with six classroom teachers and two additional teaching staff. In terms of infrastructure, the school has six classrooms, one library with a limited book collection, four school tablets, and one projector. Internet connectivity is available but unstable.

Based on an analysis of school evaluation documents and interviews with the principal, several fundamental challenges include: (1) most teachers still rely on lecture-based methods as their primary teaching approach; (2) a lack of quality reading materials to support literacy; (3) a curriculum considered too dense, limiting time for in-depth exploration; and (4) diverse socioeconomic backgrounds among students, with some coming from fishing families where parents have limited time to assist with homework at home. The principal stated: “We realize that the old way of teaching cannot be sustained. Our students need to learn to think, not just memorize.”

2. Baseline Literacy and Numeracy Levels

Prior to the implementation of deep learning, a diagnostic assessment was conducted on 30 students in grades 4-6 using an instrument adapted from the minimum competency assessment format of the Ministry of Education, Culture, Research, and Technology. The literacy instrument measured reading comprehension, text interpretation, and reflective writing skills. The numeracy instrument measured contextual calculation skills, understanding of number concepts, and solving real-world mathematical problems. The assessment results are presented in Table 2 and Figure 1.

Table 2. Initial Diagnostic Assessment Results for Literacy and Numeracy

Aspect	High Category (>80%)	Satisfactory Category (60–80%)	Low Category (<60%)	Average
Literacy	23% (7 students)	37% (11 students)	40% (12 students)	62%
Numeracy	18% (5 students)	42% (13 students)	40% (12 students)	60%

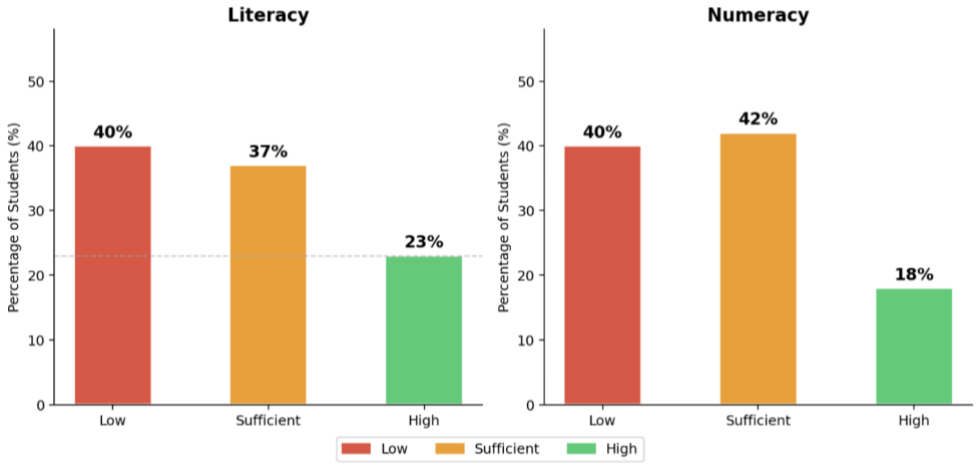

Figure 1. Distribution of Student Literacy and Numeracy Achievement Categories at Initial Diagnostic Assessment

The data in Table 2 and Figure 1 show that the distribution of initial achievement levels is deeply concerning: 40% of students fall into the low category for both skills, and only 23% (literacy) and 18% (numeracy) reach the high category. In-depth interviews with teachers revealed that students' main difficulties in literacy centered on: understanding long informational texts, the ability to make inferences, and expressing ideas in writing. As for numeracy, the biggest obstacles were the application of mathematical concepts in contextual problems and the understanding of fractions and ratios.

3. Implementation Process of the Deep Learning Approach

The implementation of deep learning took place over three months and was divided into three interconnected phases. Each phase was designed to progressively build students' literacy and numeracy skills through three dimensions: mindful, meaningful, and joyful learning.

Phase 1 - Orientation and Familiarization. In this phase, teachers re-orient their roles from information providers to learning facilitators. Key activities include: brief teacher training on the principles of deep learning; redesigning instructional modules to integrate elements of reflection, contextualization, and gamification; and establishing new classroom routines such as morning reflection and exit tickets. In the mindful learning phase, teachers begin each session with a prompt question that activates prior knowledge and encourages students to articulate their own learning goals.

Phase 2 - Core Implementation. This phase is the core of the implementation, during which the three dimensions of deep learning are applied in an integrated manner in every learning session. In meaningful learning, students work on contextual projects such as "I Am an Information Expert" (reading, summarizing, and presenting information from reading texts) for literacy, as well as "Market Math" (calculating prices, change, and profit in a buying and selling simulation) for

numeracy. In joyful learning, card-based word games, digital quizzes using tablets, and creative storytelling activities are integrated to reinforce conceptual understanding while fostering a passion for learning.

Phase 3 - Consolidation and Reflection. The final phase focuses on consolidating understanding and deep reflection. Students create a deep learning portfolio documenting their learning journey, including achievements, challenges, and successful strategies they have developed. Cross-class reflective discussion sessions are also held to share experiences and lessons learned.

4. Post-Implementation Literacy and Numeracy Outcomes

After three months of intervention, a follow-up assessment was conducted on the same 30 students using a parallel instrument. A comparison of the results is presented in Figure 2.

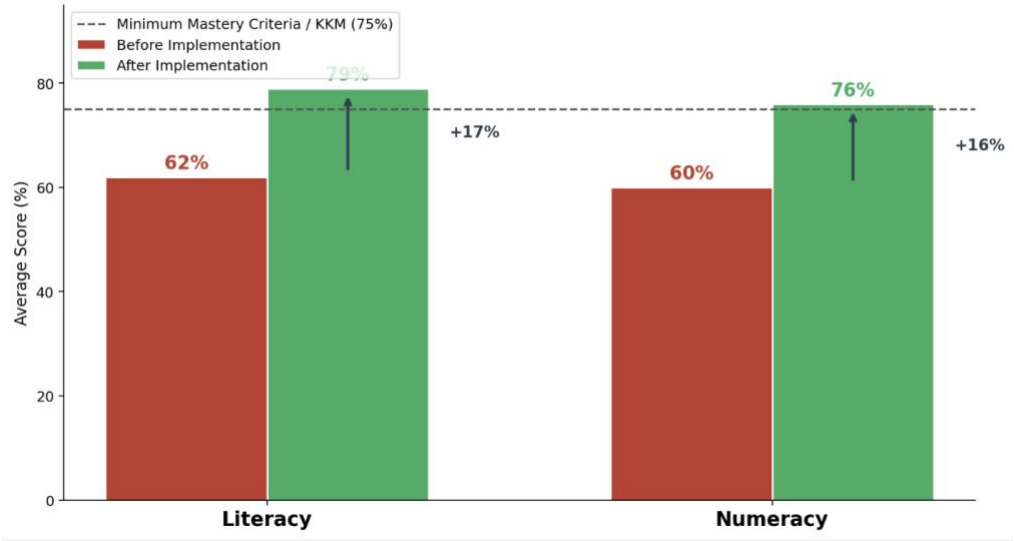

Figure 2. Comparison of Literacy and Numeracy Achievement Before and After Deep Learning Implementation

Figure 2 visually highlights the substantial improvement achieved. Both areas now exceed the school's minimum passing score (75%) an achievement that had not been reached in the previous three semesters. A deeper analysis of individual performance shows that of the 12 students who were originally in the low literacy category, 9 of them successfully moved up to the adequate or high category. For numeracy, of the 12 students in the low category, 8 students improved to a higher category. Only 3 students have not yet shown significant improvement, and individual case analyses reveal that these three students have special needs requiring more intensive intervention.

5. Monthly Development Trends

To gain a more detailed understanding of development patterns, the formative assessment data collected each month was also analyzed. The monthly development trends are presented in Figure 3.

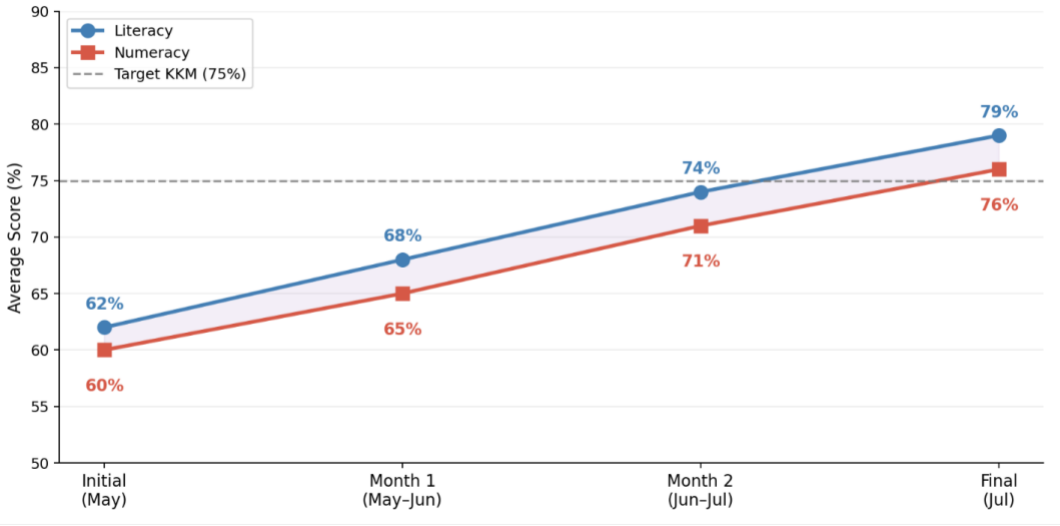

Figure 3. Trend of Literacy and Numeracy Achievement Development during Deep Learning Implementation

Figure 3 shows a consistent and progressive pattern of development. In the first month, the improvement achieved was relatively moderate (literacy: 6 points; numeracy: 5 points), indicating a period of student adaptation to the new learning approach. In the second month, the rate of improvement accelerated significantly (literacy: another 6 points; numeracy: 6 points), coinciding with the core implementation phase in which contextual projects began to run in full swing. By the end of the third month, peak performance was achieved, with both aspects exceeding the minimum competency standard. This acceleration pattern indicates that the process of internalizing the deep learning approach requires an initial adaptation period; however, once momentum is established, improvement proceeds more rapidly and sustainably.

6. Teachers' and Students' Perceptions

A thematic analysis of the interview data yielded four main themes that illustrate the comprehensive impact of deep learning implementation. The thematic findings are presented in a structured format in Table 3.

Table 3. Thematic Findings from Multi-Stakeholder Interviews

Theme	Teacher Perception	Student Perception	Parent Perspective
Motivation to Learn	Students are much more enthusiastic and do not need to be asked to actively participate	"Learning is fun now; I always look forward to tomorrow's lesson"	Children talk more about school activities at home
Conceptual Understanding	Students can explain concepts in their own words, rather than just memorizing	"Learning math now is like solving real puzzles"	Children can help calculate grocery bills correctly
Social Skills & Collaboration	Interactions among students are much more dynamic and productive	"We like group work because we can share ideas"	Children are more confident speaking in front of others
Challenges and Adaptations	Designing deep learning modules requires more preparation time	"Initially confused by the different learning approach"	It takes time to understand project-based homework

The results of this thematic analysis are supported by data on teachers' perceptions, as visualized in Figure 3. The figure presents a comparison of the percentage of positive responses from teachers before and after the implementation of the deep learning approach across five key learning dimensions: student motivation, conceptual understanding, social skills, technology integration, and student creativity. Overall, Figure 3 shows a significant and consistent increase across all measured dimensions, indicating that the impact of deep learning is not only felt directly by students but is also widely recognized by teachers as the implementers of learning.

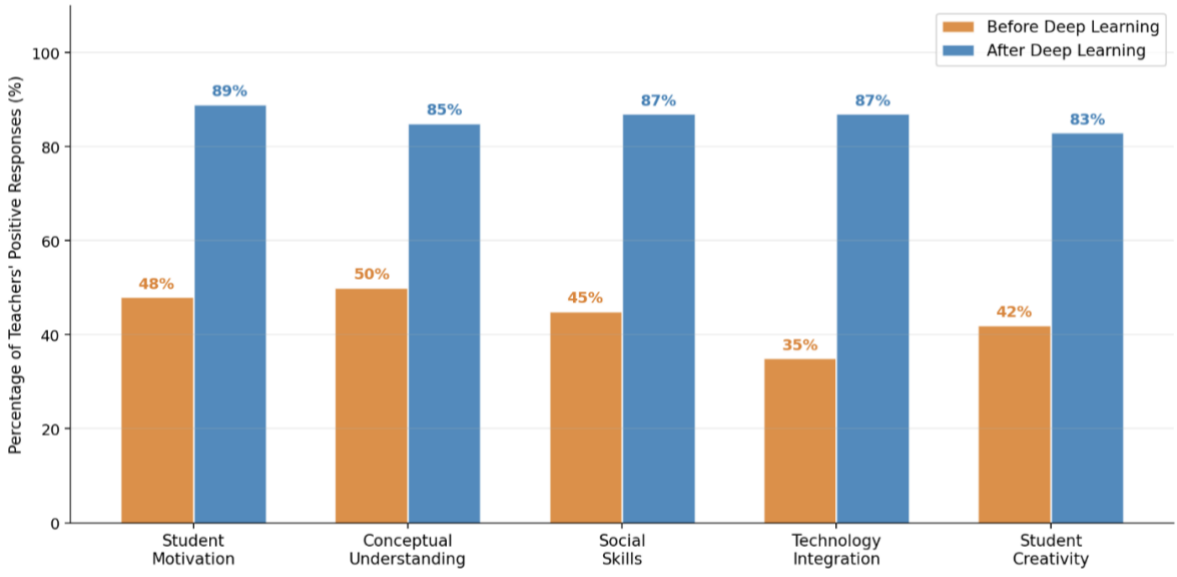

Figure 3. Teachers' Perceptions of Deep Learning's Impact

on Student Learning Dimensions

Figure 3 shows that all measured dimensions of learning saw a dramatic increase in teacher ratings. The percentage of positive teacher responses regarding student motivation increased from 48% to 89%, conceptual understanding from 50% to 85%, social skills from 45% to 87%, technology integration from 35% to 87%, and student creativity from 42% to 83%. These data indicate that the impact of deep learning is multidimensional not limited to academic achievement alone, but also encompassing character development and 21st-century skills.

7. Factors Supporting and Hindering Implementation

Based on data triangulation from observations, interviews, and documentation, a number of factors influencing the success of deep learning implementation were identified. These factors are presented comprehensively in Table 4.

Table 4. Factors Supporting and Hindering Deep Learning Implementation

No.	Supporting Factors	Barriers
1	Strong commitment from the principal as a driver of innovation and provider of resource support	Limited regular class time for in-depth projects (heavy curriculum load)
2	High collaboration among teachers in designing and evaluating shared teaching modules	Uneven mastery of deep learning principles among all teachers
3	Availability of basic digital devices (4 tablets and 1 projector)	Disparities in digital infrastructure across classrooms; unstable internet connection
4	High student motivation toward project-based and play-based learning approaches	Limited collection of quality reading materials in the school library
5	Increased parental support after observing positive changes in their children	Some parents struggle to assist with project assignments at home due to work commitments

DISCUSSION

1. Deep Learning and Literacy Improvement: A Constructivist Perspective

The 17 percentage point increase in literacy achievement obtained through the implementation of deep learning reflects the success of this approach in shifting the learning paradigm from knowledge transmission toward meaningful knowledge construction. This finding aligns with the research, which confirms that deep learning significantly fosters students' reflective and applied skills (O'Toole et al., 2026; Taqiyya et al., 2025). Theoretically, this achievement can be explained through Vygotsky's social constructivism framework, which emphasizes two key mechanisms: the zone of proximal development (ZPD) and scaffolding (Panhwar et al., 2025; Sarmiento et al., 2022). In the implementation of meaningful learning, teachers act as scaffolders who systematically help students bridge the gap between what they can do independently and what they can achieve with guidance. Text-based discussions, reflective journals, and oral presentations consistently activate higher-order cognitive processes analysis, evaluation, and creation which form the foundation of deep literacy.

The mindful learning component makes a specific contribution to improving literacy through the mechanism of metacognitive awareness. When students are routinely asked to reflect on their understanding, identify parts of the text they do not yet understand, and formulate their own questions, they actively develop metacognitive awareness, which is a strong predictor of reading comprehension success. Flavell has long identified that effective reading ability depends heavily on the reader's ability to monitor and regulate their own comprehension process a capacity that is explicitly trained in mindful learning (Lusnig et al., 2023).

Critically, the 17 percentage-point improvement observed in this study exceeds the gains reported in comparable interventions. For instance, documented moderate improvements in reflective thinking skills following deep learning implementation but did not specifically measure literacy outcomes through standardized indicators. Similarly focused on critical thinking rather than literacy achievement metrics (Giselsson, 2020). This suggests that the simultaneous and integrated application of all three deep learning dimensions rather than partial adoption may be a critical differentiating factor in producing stronger gains. Furthermore, the contextual grounding of learning activities in students' immediate social realities (fishing community contexts, local market activities) likely amplified the motivational and cognitive benefits of the approach, a mechanism that remains undertheorized in the existing literature and represents an important direction for future inquiry.

2. Deep Learning and Numeracy Improvement: Contextualizing Mathematics

A 16 percentage point increase in numeracy indicates that mathematics learning contextualized in real life is far more effective than the procedural-symbolic approach that has dominated until now. This finding supports the central argument that the connection between

mathematics and real-world contexts is one of the most important factors in improving student motivation and numeracy achievement (Lubis, 2025; Marisa et al., 2023; Marisa & Santi, 2025). The "Market Math" project, in which students simulate buying and selling transactions, calculate profit margins, and create simple financial reports, creates an authentic context that makes mathematics relevant and meaningful to students' lives.

It is worth noting that the improvement in numeracy is not limited to computational skills (calculations) but also extends to more complex problem-solving. This indicates that deep learning successfully fosters deeper mathematical reasoning an achievement that is difficult to attain through drills and formula memorization. Interviews with students reveal a significant shift in mindset: from "math is a difficult and boring subject" to "math is a tool for solving real-world problems." This dispositional shift is a fundamental prerequisite for the long term development of mathematical literacy (Fadlillah et al., 2025; Marisa et al., 2023). This finding merits critical reflection in comparison with prior research. The Realistic Mathematics Education (RME) approach, which shares the principle of contextualizing mathematics in real life, has similarly produced meaningful gains in student motivation (Lubis, 2025b); however, RME literature predominantly addresses computational fluency rather than the broader dispositional and collaborative dimensions documented here (Siswantari et al., 2025). The 16 percentage-point numeracy gain in the present study is particularly notable given the resource-constrained context: it was achieved with minimal digital infrastructure, suggesting that pedagogical design quality rather than technological investment is the primary driver of numeracy improvement. This challenges assumptions prevalent in educational technology discourse and underscores the urgency of teacher professional development as a policy priority in under-resourced regions.

3. Affective and Social Dimensions: Beyond Academic Achievement

One of the most significant findings of this study is that the impact of deep learning extends beyond academic achievement. Dramatic changes in the affective dimension increased motivation, self-confidence, and enthusiasm for learning and the social dimension collaboration, communication, and empathy confirm that this approach successfully addresses aspects of learning that have long been neglected in the exam-based education paradigm. The component of joyful learning plays a crucial role in this affective transformation. When learning is designed to be enjoyable and relevant, students' intrinsic motivation which is the strongest predictor of long-term academic achievement naturally grows (Kamberi, 2025; Tomasik et al., 2021).

Findings regarding improvements in collaboration skills also have important implications. The data in Figure 3 show that 87% of teachers reported a significant improvement in the quality of group work. Student interviews revealed that the collaborative project format not only fosters interpersonal skills but also strengthens conceptual understanding through peer teaching and collaborative knowledge construction. Vygotsky identified social interaction as a fundamental

mechanism in knowledge construction an argument that receives strong empirical support in the findings of this study (Taber, 2025). These affective and social findings carry broader critical significance. In the context of Indonesian elementary education, which has historically prioritized cognitive test scores and exam preparation, the documentation of meaningful improvements in motivation, self-confidence, and collaborative competency represents a paradigmatic shift in how educational quality is conceptualized and measured (Cahyanto, 2025). Demonstrated through a natural experiment during COVID-19 school closures that in-person, socially-embedded learning produces substantially greater developmental gains than isolated instruction a finding that directly corroborates why joyful and collaborative deep learning activities generated such pronounced affective improvements in this study. The implication for assessment policy is clear: Indonesia's evaluation frameworks must evolve beyond minimum competency assessment scores to capture the full spectrum of competencies that deep learning fosters, lest the most educationally significant outcomes of such innovations remain invisible and thus unsupported by policy.

4. Implications for Technology Integration

The finding that 87% of teachers reported that integrating digital technology into learning through a deep learning approach was easy is a relevant observation in the context of Indonesia's educational digital transformation. Interestingly, the implementation at SD Negeri 11 Jangka demonstrates that effective technology integration does not require sophisticated infrastructure four tablets and one projector are sufficient when utilized creatively within a joyful learning framework. This has important implications for schools in peripheral areas with similar resource constraints, indicating that pedagogical innovation not massive technological investment is the key to success.

5. Research Limitations and Directions for Future Research

This study has several limitations that must be honestly acknowledged. First, as a case study of a single school, these findings cannot be statistically generalized to a broader population. Second, the three-month duration may not be sufficient to capture the long-term impact of the implementation. Third, the Hawthorne effect where behavioral changes occur because subjects feel they are being observed cannot be entirely ruled out. These limitations open opportunities for further research using longitudinal, multi-school designs, or mixed-methods approaches with control groups to obtain stronger evidence regarding the effectiveness of deep learning in the context of Indonesian elementary education.

CONCLUSION

This study provides strong empirical evidence that the implementation of a deep learning approach through the integration of mindful, meaningful, and joyful learning dimensions is an

effective, innovative, and practical pedagogical solution for addressing literacy and numeracy challenges in elementary schools. Three main conclusions can be drawn. First, deep learning measurably improves students' literacy and numeracy achievements. A 17-percentage-point increase in literacy and a 16-point increase in numeracy achieved over three months indicate the effectiveness of this approach in shifting the learning paradigm from rote memorization toward deep understanding. Second, both components met and exceeded the school's minimum competency standard (75%), an achievement never reached in the previous three semesters. Second, the impact of deep learning is multidimensional and holistic. In addition to academic achievements, there was a significant transformation in the affective dimension (motivation, self-confidence, enthusiasm) and the social dimension (collaboration, communication, presentation skills). These changes represent the development of 21st-century skills that cannot be measured solely through cognitive tests, yet are crucial for students' readiness to face future challenges. Third, the successful implementation of deep learning requires a comprehensive support ecosystem: visionary and supportive school leadership, professional collaboration among teachers, and active parental involvement. Without synergy among these three elements, even the best learning approaches will face significant implementation challenges. Based on these findings, this study recommends: (1) replicating the deep learning approach in other elementary schools with similar characteristics, accompanied by careful contextual adaptation; (2) implementing systematic and ongoing professional development programs for teachers, focusing on mastering the principles of mindful, meaningful, and joyful learning; (3) the development of an assessment system capable of measuring not only cognitive achievements but also the affective and social dimensions of deep learning; and (4) further research with a longitudinal and multi-school design to strengthen the scientific evidence base for the effectiveness of this approach in the context of Indonesian elementary education. The findings of this study are expected to have a meaningful impact on educational policy and practice, particularly in providing an evidence-based, replicable model for improving literacy and numeracy quality in elementary schools across Indonesia, especially those operating in peripheral and resource-constrained contexts

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