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TRANSFORMING CHEMISTRY LEARNING THROUGH DEEP LEARNING: AN EVALUATION WITH CIPP MODEL

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Abstract. Deep learning has emerged as a transformative pedagogical approach that emphasizes mindful, meaningful, and joyful learning experiences. In the context of chemistry education, this approach encourages students to connect scientific concepts with real-life situations and to develop higher-order thinking skills aligned with the Merdeka Curriculum. This study aims to evaluate the implementation of the deep learning approach in chemistry education through the Context, Input, Process, and Product (CIPP) evaluation model. A qualitative evaluative design was employed, involving classroom observations, document analysis, and interviews with teachers and students. Data were analyzed inductively to capture the processes, impacts, and challenges of deep learning implementation in school settings. The findings indicate that the principles of deep learning, though not yet formally institutionalized, have been partially applied in chemistry instruction. Teachers and students demonstrated positive engagement in connecting learning materials to real-world contexts. The learning environment supports active participation and enhances students' conceptual understanding and motivation. However, challenges remain, including limited teacher training, time constraints, and varying student competencies. The study concludes that deep learning holds strong potential for improving the quality of chemistry education when supported by professional development, institutional facilitation, and curriculum alignment. Effective implementation of this approach can further realize the objectives of the Merdeka Curriculum and nurture students' critical and creative capacities.

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INTRODUCTION

Education is a living system that continuously evolves to respond to social, cultural, and technological changes. At its core lies the curriculum, which serves as both a guide and a mirror of educational philosophy. It articulates goals, methods, and content, shaping how learning is designed and experienced by students (Arifa et al., 2025). Just as a strong foundation ensures the stability of a structure, a well-designed curriculum determines the coherence and effectiveness of educational practices (Tambusai et al., 2024).

A curriculum must be dynamic and responsive to contemporary demands (Sri Rahayu et al., 2023). Indonesia's current educational transformation, embodied in the Merdeka Curriculum, reflects this dynamism. The curriculum promotes flexibility and autonomy for teachers in designing learning activities that are meaningful, relevant, and aligned with students' needs (Sari, 2023). It also encourages technology integration, project-based learning, and inquiry-driven approaches that foster authentic learning experiences (Sukini, 2025).

Ensure that the Merdeka Curriculum achieves its intended goals, pedagogical practices must align with its humanistic and constructivist values (Amir et al., 2024). One such approach is deep learning, a framework that focuses on nurturing understanding through reflection, connection, and authentic engagement rather than rote memorization. This concept, popularized by (Fullan et al., 2018)It emphasizes cultivating six global competencies: critical thinking, creativity, communication, collaboration, character, and citizenship as foundations for lifelong learning.

Deep learning encourages students to engage mindfully and meaningfully in their learning experiences (Feriyanto & Anjariyah, 2024). It situates learners as active constructors of knowledge who explore real-world contexts to internalize abstract concepts (Wijaya et al., 2025). Such an approach aligns with 21st-century competencies that highlight problem-solving and adaptive thinking skills (Wardani & Fiorintina, 2023).

Chemistry, as a discipline inherently connected to daily life, air, food, and environmental processes provides fertile ground for implementing deep learning (Majid & Rohaeti, 2018;Ratna et al., 2023). When learners can relate chemical phenomena to real situations, their curiosity and conceptual depth increase (Jere & Mpeta, 2024).

However, several studies show that the integration of deep learning into science education remains limited. For instance, Andrews et al. (2020), found that teachers often interpret deep learning merely as project-based learning without addressing its reflective and conceptual depth. Similarly, Schafer & Yezierski (2021) reported that the implementation of deep learning in chemistry was constrained by teachers' unfamiliarity with designing authentic assessments (Nofamataro & Zebua, 2025). Meanwhile, Heriyadi et al. (2025) highlighted the gap between policy and practice, where teachers tend to focus on curriculum compliance rather than pedagogical transformation. Hendrickx et al. (2025) added that professional learning communities play a significant role in shaping teachers' understanding of deep learning principles.

Compared with these previous studies, this research differs in two important aspects. First, it evaluates the implementation of deep learning using the CIPP (Context, Input, Process, Product) evaluation model, enabling a more holistic understanding of pedagogical implementation rather than focusing solely on classroom practices. Second, it emphasizes the interconnection between deep learning and the Merdeka Curriculum, exploring how both can synergistically improve the quality of chemistry education (Sari & Putra, 2025).

Previous research indicates that the implementation of deep learning pedagogy is influenced by teacher readiness and understanding of curriculum demands. Fitrah et al. (2025) described teacher readiness at a moderate level, with challenges in digital skills and conceptual understanding. This study expands the analysis through the CIPP model, which examines the context, input, process, and product of Chemistry learning more comprehensively. Rintayati (2023) and Liu et al. (2024) emphasized the role of PLCs in enhancing digital competence and teacher collaboration. This study links PLC-based competency strengthening with the implementation of deep learning within the Independent Curriculum framework.

Studies on interdisciplinary collaboration have demonstrated significant contributions to learning innovation. Li & Jamil (2024) found that PLCs create collaborative spaces that encourage cross-disciplinary integration. This study leverages these findings to strengthen the relevance of deep learning-based Chemistry learning. Annisa et al. (2024) demonstrated increased student resilience and learning outcomes through contextualized learning experiences. This study links these learning experiences with the mindful-meaningful-joyful framework, a fundamental characteristic of the deep learning approach to Chemistry.

Learning technology and institutional support play a crucial role in the success of deep learning. Cresswell et al. (2024) found that digital interactivity enhances student motivation, conceptual understanding, and engagement. This study incorporated aspects of digital interactivity into process and product evaluation using the CIPP model. Dacholfany et al. (2024) emphasized the role of school leadership and management in sustaining pedagogical innovation. This study places institutional readiness across all CIPP dimensions as the basis for innovation through the integration of deep learning pedagogy, PLCs, digital interactivity, and comprehensive evaluation in the context of chemistry learning. Therefore, this study contributes a novel perspective by integrating the CIPP model as an evaluative lens for understanding deep learning practices in chemistry education. This provides not only an empirical description of implementation but also a conceptual bridge between curriculum reform and pedagogical innovation. Specifically, this study aims to: (1) describe the process of implementing the deep learning approach in chemistry education; (2) identify the challenges encountered during its implementation; (3) analyze the impacts of deep learning on students' engagement and learning outcomes.

The findings are expected to contribute both theoretically and practically. Theoretically,

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they enrich the discourse on deep learning as a pedagogical approach that harmonizes with the Merdeka Curriculum. Practically, they offer insights for educators, policymakers, and institutions in strengthening teacher capacity, curriculum alignment, and authentic learning practices in chemistry education.

RESEARCH METHODS

This study employed a qualitative evaluative approach based on the CIPP model (Context, Input, Process, Product). The CIPP model was chosen because it provides a comprehensive framework for evaluating educational innovations by examining their relevance, feasibility, implementation, and outcomes. Through this approach, the research seeks to gain a holistic understanding of how the deep learning approach is implemented in chemistry instruction and how it aligns with the objectives of the Merdeka Curriculum.

The study was conducted at Senior High School 4 Bogor, located in South Bogor District, Indonesia. This school was purposively selected because it has begun integrating elements of deep learning in chemistry instruction as part of its effort to adapt to the Merdeka Curriculum. The participants consisted of the school principal, the vice principal for curriculum, chemistry teachers, and grade XI students. They were selected using purposive sampling based on their involvement and experience in implementing deep learning in classroom practice, ensuring that each participant could provide relevant and rich information about the program.

The research process followed several systematic stages, illustrated in Figure 1, which outlines the overall steps of the study from problem identification to reporting. The process began with identifying the research problem and conducting a comprehensive literature review to establish the theoretical foundation and identify research gaps. This was followed by research design development, where the framework and instruments were aligned with the four dimensions of the CIPP model. The next stage involved instrument development and validation, in which interview guidelines, observation checklists, and questionnaires were reviewed by two experts in educational evaluation and chemistry education to ensure their validity. The subsequent stages were data collection, data analysis, and finally, report preparation. Each phase was carefully designed to ensure coherence between research objectives and analytical methods. Figure 1 presents the research steps used in evaluating the implementation of deep learning in chemistry instruction using the CIPP model.

Figure 1. Research Step

RESULTS AND DISCUSSION

The implementation of the deep learning approach at SMA Negeri 4 Bogor remains in its preparatory stage, with formal integration scheduled for the 2025 academic year. Data gathered through interviews, observations, and surveys were analyzed according to the CIPP model (Context, Input, Process, Product) to provide a holistic evaluation of the school's readiness, strategies, and outcomes.

Context Evaluation

In the context dimension, SMA Negeri 4 Bogor demonstrates institutional readiness and philosophical alignment with the Merdeka Curriculum, which emphasizes learner autonomy,

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flexibility, and meaningful engagement. According to the Vice Principal for Curriculum Affairs, deep learning is perceived not only as a new pedagogical directive but also as a strategic response to the zoning policy that has diversified student backgrounds and academic abilities.

The Vice Principal emphasized that although formal implementation has not yet begun, the school has initiated several preparatory actions, such as internal discussions and limited exposure through webinars for teachers. This reflects the institution's early-stage engagement and proactive adaptation to educational reform.

The school's vision to nurture graduates with integrity, collaboration skills, and lifelong learning habits is strongly aligned with the goals of deep learning. This contextual foundation resonates with the view of Fullan et al. (2018) who stated that sustainable educational innovation begins with shared cultural readiness rather than mere policy compliance.

Input Evaluation

From an input perspective, SMA Negeri 4 Bogor has adequate physical and digital resources to support pedagogical innovation. The school is equipped with chemistry laboratories, a two-story library, sports facilities, and digital technologies, including projectors, computers, and stable internet connectivity. These facilities enable technology-enhanced and student-centered learning (Ling Huang et al., 2022; Kerimbayev et al., 2023).

However, the main challenge lies in teacher preparedness. The chemistry teacher revealed during interviews that most teachers have a limited understanding of deep learning, having been introduced only once through an online seminar. This gap illustrates the need for structured and continuous professional development, a finding consistent with Hattie & Timperley (2007), who emphasized that pedagogical success relies on teacher expertise and reflective capacity.

The absence of standardized instructional materials tailored to deep learning also constrains implementation. Teachers have to design lesson plans independently, leading to inconsistent practices across classes. As highlighted by Sanabria et al. (2024), contextualized and flexible teaching resources are essential for fostering pedagogical innovation and enabling adaptive instruction that aligns with learners' diverse needs.

Process Evaluation

The process dimension focuses on how deep learning principles are operationalized in classroom practice. Chemistry teachers at SMA Negeri 4 Bogor have begun applying contextual learning, connecting abstract chemical concepts to real-world experiences. For instance, students used natural indicators such as turmeric to identify acids and bases, reflecting meaningful and experiential learning (Sri Rahayu et al., 2023).

Teachers reported that these activities have transformed the classroom dynamic, students are more active, discussions are more interactive, and the teacher's role has shifted from knowledge provider to learning facilitator. These findings align with Wijaya et al. (2025), who found that deep learning fosters inquiry-based and reflective engagement among students.

The outcomes of student surveys further support these observations. Figure 2 illustrates that 50% of students agreed that their awareness increased when learning chemistry through deep learning, while 50% were uncertain. This result implies partial but emerging mindfulness among learners, suggesting that deeper conceptual understanding is gradually forming.

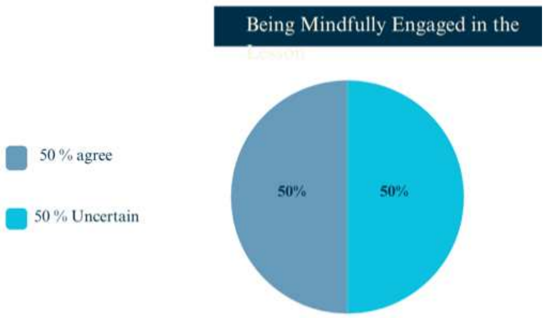

Figure 2. Survey Results on Students' Awareness in Chemistry Learning

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In Figure 3, all students (100%) reported increased interest and motivation when deep learning was implemented in chemistry lessons. This demonstrates that joyful learning—a key component of deep learning—is already being realized in practice (Fitriani & Santiani, 2025).

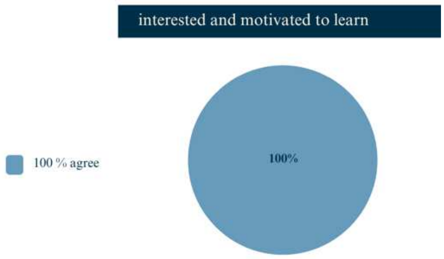

Figure 3. Survey results related to students' interest and motivation

Likewise, Figure 4 shows that 100% of students perceived chemistry learning through deep learning as highly relevant to everyday life. This confirms the *meaningful learning* aspect, where students can connect classroom lessons to authentic contexts (Hayati Dahlan et al., 2023; John & Chaterine, 2011).

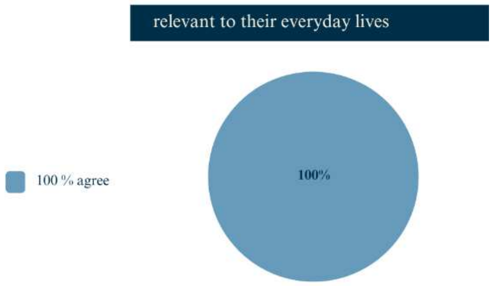

Figure 4. Survey results on students' perception of Chemistry learning as relevant to everyday life

Together, Figures 2-4 illustrate that early-stage implementation of deep learning has already enhanced students' awareness, motivation, and relevance of learning. This supports findings from Ling Huang et al. (2022) and Hwang & Chang (2011)**,** who reported that contextual learning environments increase both engagement and cognitive depth.

However, process-related challenges persist. Teachers face time constraints, heavy administrative loads, and the need to differentiate instruction according to students' varied learning styles. These constraints echo findings by Diputera et al. (2024), emphasizing that pedagogical innovation must be balanced with workload reform to be sustainable.

Product Evaluation

The product evaluation highlights the initial outcomes of deep learning practices in chemistry instruction. Although formal implementation has yet to occur, observable benefits are evident. Students display higher motivation, stronger conceptual connections, and increased confidence in participating in discussions. These findings mirror those of Putri (2024) and Khotimah & Abdan (2025)**,** who noted that deep learning promotes critical and creative thinking.

Teachers also observed that students' engagement extended beyond academic performance, reflecting broader graduate profiles that included critical thinking, creativity, collaboration, independence, and communication. This alignment with the Merdeka Curriculum demonstrates how the deep learning approach supports holistic education and character formation, as emphasized by Barkah et al. (2025)**.**

The implementation still faces several fundamental challenges. Many teachers have not received consistent or in-depth training, and the diversity of students shaped mainly by the zoning system makes it challenging to apply deep learning evenly across classrooms. As Subban et al. (2025) observed, each learner carries a distinct rhythm and way of understanding; therefore, thoughtful differentiation in teaching becomes essential to ensure that every student can grow meaningfully within the same learning environment.

Overall, SMA Negeri 4 Bogor demonstrates institutional commitment, teacher enthusiasm,

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and student readiness for transformative pedagogy. However, sustained investment in professional development and instructional design is vital for ensuring long-term success (Fullan et al., 2018).

To synthesize the findings from each dimension of the CIPP model, the key aspects of context, input, process, and product evaluations are summarized in Table 1. This table provides a comprehensive overview of how the deep learning approach has been prepared, implemented, and evaluated within the chemistry learning environment at SMA Negeri 4 Bogor.

Table 1. Summary of Research Findings Based on the CIPP Model

Component	Findings
Context	Early readiness and alignment between school vision and deep learning objectives. Preliminary awareness-building efforts initiated.
Input	Adequate infrastructure, moderate teacher readiness, and limited instructional materials. Strong administrative support.
Process	Informal integration of deep learning principles in chemistry lessons. Positive student response reflected in Figures 4–6.
Product	Increased motivation, participation, and conceptual understanding. Further professional development is needed for full-scale implementation.

As shown in Table 1, the findings reflect a coherent relationship among the four CIPP components. The context dimension highlights that SMA Negeri 4 Bogor has built a strong philosophical and strategic foundation for implementing the deep learning approach. The school's vision and mission are well aligned with the goals of the Merdeka Curriculum, promoting autonomy, collaboration, and lifelong learning. This alignment provides a favorable environment for pedagogical innovation (Fullan et al., 2018).

In the input dimension, the school exhibits adequate facilities and digital infrastructure that support interactive and student-centered learning. However, teacher readiness remains moderate due to limited training and a lack of formal instructional materials. This confirms that educational reform must be supported by continuous professional development (Xie et al., 2025).

The process dimension reveals that although implementation is still informal, deep learning practices have already begun to shape chemistry learning. Teachers have encouraged students to relate concepts to real-world contexts, leading to more engaging and reflective classroom experiences. The student survey results presented in Figures 2–4 validate this process by showing increased awareness, motivation, and relevance in learning. These findings align with studies by Wijaya et al. (2025) which underscores the effectiveness of active learning in fostering engagement and conceptual understanding.

Finally, the product dimension shows tangible yet preliminary impacts. Students demonstrate higher motivation and participation, indicating that even early-stage implementation can create positive outcomes. However, challenges such as time constraints, diverse student abilities, and administrative burdens continue to limit optimal results. Addressing these issues through targeted teacher training and policy adjustments will be critical to sustaining improvement (Diputera et al., 2024).

Overall, the analysis across the four CIPP dimensions confirms that SMA Negeri 4 Bogor has established a promising foundation for the deep learning approach. With continued institutional support, structured professional development, and consistent evaluation, the school is positioned to transform its chemistry instruction into a more meaningful, student-driven learning experience. Recent meta-analytic research shows that well-designed professional development programs significantly increase teachers' self-efficacy in STEM education, thereby contributing to the effectiveness and sustainability of deep learning initiatives (Liu et al., 2025).

CONCLUSIONS AND SUGGESTIONS

Based on the findings and analysis, it can be concluded that while the deep learning approach has not been formally implemented at SMA Negeri 4 Kota Bogor, its core principles of

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mindful, meaningful, and joyful learning are already present in chemistry instruction. This application has positively impacted students by fostering greater active engagement, as lessons are directly connected to their real-life experiences. However, challenges to full implementation remain, including the absence of formal teacher training, the time-intensive nature of the approach, and the continued burden of administrative tasks on teachers. To support the successful integration of deep learning, it is recommended that schools organize structured, comprehensive training for teachers to build confidence and pedagogical alignment, while streamlining administrative duties to free up time for personalized student engagement. Furthermore, learning strategies should be designed to accommodate diverse student needs, allowing for self-paced progress without compromising core curricular objectives. By addressing these areas, schools can foster a more inclusive, innovative, and effective learning environment aligned with the values of the Merdeka Curriculum and the principles of deep learning.

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