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# IMPLEMENTING DEEP LEARNING IN SCIENTIFIC WRITING INSTRUCTION: ENHANCING STUDENTS' CRITICAL THINKING AND ACADEMIC WRITING SKILLS IN VOCATIONAL EDUCATION

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**Abstract**
Scientific writing is an essential literacy competency in vocational education because it requires students to integrate empirical experience, conceptual understanding, evidence, and systematic communication. However, students often experience difficulties in developing scientific arguments and tend to rely on surface learning and reproduction of information. This study examines the implementation of a Deep Learning approach in scientific writing instruction among Grade 11 students at UPTD SMK Negeri Rea Timur, Polewali Mandar, West Sulawesi, Indonesia. Using an interpretive qualitative design with a hermeneutic perspective, the study explored how mindful, meaningful, and joyful learning were integrated into the scientific writing process. Data were collected through participatory observation, semi-structured interviews, and document analysis of lesson plans, student reflections, assessment instruments, and scientific writing drafts. Data were analyzed using the interactive model of data condensation, data display, and conclusion drawing and verification, with credibility strengthened through triangulation and member checking. The findings indicate that Deep Learning supported a shift from reproductive learning toward reflective and knowledge-constructive learning. Students became more aware of their thinking processes, connected vocational experiences with academic concepts, and developed more original arguments grounded in empirical evidence. Discussion, scaffolding, peer feedback, and revision further supported progressive improvement in writing quality. Nevertheless, implementation was constrained by surface-learning habits, varied literacy levels, limited instructional time, and difficulties connecting empirical data with theory. The study highlights Deep Learning as an integrated pedagogical orientation for contextually grounded scientific writing instruction in vocational education.
**Keywords:** deep learning, scientific writing, mindful learning, meaningful learning, joyful learning, vocational education, qualitative study

***Abstrak***
*Penulisan ilmiah merupakan kompetensi literasi yang esensial dalam pendidikan vokasional karena menuntut siswa untuk mengintegrasikan pengalaman empiris,*

*pemahaman konseptual, bukti, dan komunikasi secara sistematis. Namun, siswa sering mengalami kesulitan dalam mengembangkan argumentasi ilmiah dan cenderung mengandalkan pembelajaran permukaan serta reproduksi informasi. Penelitian ini bertujuan untuk mengkaji implementasi pendekatan Deep Learning dalam pembelajaran penulisan ilmiah pada siswa kelas XI di UPTD SMK Negeri Rea Timur, Polewali Mandar, Sulawesi Barat, Indonesia. Dengan menggunakan desain kualitatif interpretif dalam perspektif hermeneutik, penelitian ini mengeksplorasi bagaimana prinsip mindful, meaningful, dan joyful learning diintegrasikan ke dalam proses penulisan ilmiah. Data dikumpulkan melalui observasi partisipatif, wawancara semi-terstruktur, dan analisis dokumen yang meliputi perangkat pembelajaran, refleksi siswa, instrumen penilaian, dan draf tulisan ilmiah. Data dianalisis menggunakan model interaktif melalui kondensasi data, penyajian data, serta penarikan dan verifikasi kesimpulan, dengan kredibilitas diperkuat melalui triangulasi dan member checking. Hasil penelitian menunjukkan bahwa Deep Learning mendukung pergeseran dari pembelajaran reproduktif menuju pembelajaran reflektif dan konstruktif dalam membangun pengetahuan. Siswa menjadi lebih sadar terhadap proses berpikirnya, mampu menghubungkan pengalaman vokasional dengan konsep akademik, serta mengembangkan argumentasi yang lebih orisinal berdasarkan bukti empiris. Diskusi, scaffolding, umpan balik teman sebaya, dan revisi turut mendukung peningkatan kualitas tulisan secara bertahap. Namun, implementasinya menghadapi kendala berupa kebiasaan belajar permukaan, perbedaan tingkat literasi, keterbatasan waktu pembelajaran, serta kesulitan dalam menghubungkan data empiris dengan teori. Penelitian ini menegaskan bahwa Deep Learning dapat diposisikan sebagai orientasi pedagogis integratif untuk mengembangkan pembelajaran penulisan ilmiah yang kontekstual dalam pendidikan vokasional.*
***Kata kunci:*** *deep learning, penulisan ilmiah, mindful learning, meaningful learning, joyful learning, pendidikan vokasional, penelitian kualitatif.*

## INTRODUCTION

The educational demands of the twenty-first century have shifted substantially from the transmission of factual knowledge toward the development of learners who can construct, evaluate, and communicate knowledge in meaningful ways. Contemporary education increasingly emphasizes higher-order cognitive competencies, including critical thinking, creativity, problem solving, communication, collaboration, self-regulation, and the ability to apply knowledge across contexts. Within this transformation, literacy should not be understood merely as the ability to read and write, but as the capacity to interpret information critically, evaluate evidence, construct arguments, and communicate ideas effectively. Writing therefore occupies a particularly important position because it requires learners to transform information into organized knowledge through processes of planning, reasoning, argumentation, revision, and reflection (Graham, 2020; Graham et al., 2020; Graham, 2022).

The urgency of strengthening literacy is particularly evident in the Indonesian educational context. International assessment data indicate persistent challenges in students' literacy and higher-order reasoning. The Programme for International Student Assessment (PISA) 2022 reported that only approximately one-quarter of Indonesian 15-year-old students reached Level 2 or above in reading, compared with 74% across OECD countries. Moreover, almost no Indonesian students reached the highest reading proficiency levels, which require students to comprehend complex texts, make inferences, distinguish information sources, and reason about abstract ideas (OECD, 2023). These results should not be interpreted as a direct measure of students' scientific writing competence; rather, they provide an important indication of the broader literacy environment in which students are expected to develop academic reading, reasoning, and writing abilities. The challenge is therefore not simply to increase students' exposure to written information, but to develop pedagogical environments in which learners actively process, interrogate, connect, and transform information into knowledge.

This challenge becomes more consequential when literacy development is considered within secondary vocational education. Vocational high schools (*Sekolah Menengah Kejuruan* [SMK]) have a distinctive mandate because they are expected to prepare students for further education while simultaneously developing occupational competencies relevant to professional practice. Consequently, literacy in vocational education should be connected with authentic disciplinary and workplace practices rather than treated exclusively as a general language competency. Scientific writing is particularly relevant because vocational students are required to document observations, report practical activities, formulate problems, interpret evidence, explain procedures, and communicate the results of projects or workplace experiences. In this context, scientific writing represents more than a language exercise; it is a form of knowledge construction through which students learn to transform practical experiences into systematic and evidence-based explanations.

However, writing is a cognitively demanding activity, and students cannot be expected to acquire sophisticated writing competence merely through repeated writing assignments. Recent evidence demonstrates that effective writing instruction requires explicit attention to multiple dimensions of the writing process, including planning, goal setting, inquiry, organization, drafting, revision, feedback, and the development of text structures (Graham et al., 2023; Graham et al., 2024). A large-scale meta-analysis of writing interventions for students in Grades 6–12 found that multiple instructional practices can improve students' writing, including process-oriented instruction, writing goals, inquiry and prewriting activities, peer assistance, digital writing tools, strategy instruction, and explicit instruction in text structures (Graham et al., 2023). A subsequent best-evidence meta-analysis further confirmed the importance of systematic writing instruction for adolescent learners (Graham et al., 2024). These findings suggest that scientific writing instruction should be designed as a sustained cognitive process rather than reduced to teaching formal structures such as introductions, methods, results, and conclusions.

The importance of process-oriented writing is also supported by research on self-regulated learning. Writing requires students to establish goals, monitor their progress, evaluate the quality of their arguments, identify weaknesses, and revise their texts. Research on Self-Regulated Strategy Development indicates that explicit instruction in goal setting, self-monitoring, self-instruction, and self-reinforcement can support students' academic performance, particularly when learners experience difficulties with self-regulation (Sanders et al., 2021). Similarly, research involving students with learning difficulties indicates that self-regulated strategy development can be applied to reading and writing instruction by combining explicit academic strategies with processes of self-regulation (Rogers et al., 2020). These findings are highly relevant to scientific writing because producing an academic text requires students to regulate not only what they write but also how they search for information, organize evidence, monitor coherence, and revise their reasoning.

Scientific writing is consequently better understood as a form of *learning through writing* rather than merely *writing as a learning product*. Writing can facilitate learning because it requires students to reorganize and integrate disciplinary knowledge. Graham et al. (2020), through a meta-analysis of 56 experimental studies, demonstrated that writing about content in science, social studies, and mathematics can facilitate students' learning. Graham (2020) similarly argued that reading and writing are reciprocal processes, with improvements in writing and writing instruction contributing to reading development and vice versa. Thus, scientific writing instruction can serve a dual function: developing students' communication competence while simultaneously deepening their conceptual understanding and reasoning.

Evidence from educational research also demonstrates the potential of contextual and project-oriented learning for developing writing competence. For example, Sujiono et al. (2023) found that contextual and multicultural learning materials could significantly improve students' scientific writing performance. Their findings are particularly relevant because contextualization connects scientific writing with students' prior knowledge and social or experiential contexts. Similarly, Suprihatin et al. (2023) reported that Indonesian instructional materials developed around a scientific approach influenced students' learning outcomes in scientific writing, while also highlighting the need for learning resources that support higher-order thinking. These studies suggest that the quality of scientific writing is strongly associated with how learning materials and instructional activities facilitate students' active engagement with knowledge rather than simply presenting writing conventions.

Project-based learning has likewise been identified as a potentially productive context for writing development because it positions students as active producers of knowledge. Reznani et al. (2022), for instance, found that project-based learning could improve students' academic writing skills. Suteja and Setiawan (2022) further demonstrated the relationship between critical thinking and writing skills within project-based learning. Other classroom-based studies have reported improvements in writing through project-oriented activities, including scientific reports, narrative texts, procedural texts, and other forms of academic or functional writing (Faurisiawati et al., 2022; Giawa, 2022; Phumsit & Tao-ngoen, 2022; Sumiyati, 2022). These findings collectively indicate that students' writing develops more effectively when writing is embedded in meaningful activities that require them to investigate, make decisions, solve problems, and communicate outcomes.

Nevertheless, the existence of effective writing strategies does not necessarily mean that students experience learning deeply. Conventional writing instruction may still emphasize the final product, grammatical accuracy, prescribed structure, or completion of assignments without sufficiently engaging students in the intellectual processes underlying scientific writing. This distinction is important because students may be able to reproduce the formal structure of a scientific paper without actually understanding how research questions are formulated, how evidence supports an argument, or why particular conclusions follow from the data. Such learning may produce formally acceptable texts while leaving students' conceptual understanding and epistemic reasoning relatively superficial.

This problem creates a strong rationale for examining pedagogical approaches that explicitly emphasize deeper engagement with knowledge. One approach receiving increasing attention in Indonesian educational discourse is deep learning as a pedagogical framework. In this context, *deep learning* does not refer to artificial intelligence or neural-network-based computational models. Rather, it refers to a learning orientation that seeks to move students beyond surface memorization toward deeper conceptual understanding, active engagement, reflection, and meaningful application. Recent Indonesian scholarship conceptualizes this approach through the interconnected principles of mindful learning, meaningful learning, and joyful learning (Andayanie et al., 2025; Feriyanto & Anjariyah, 2024).

The *meaningful* dimension emphasizes the relationship between new knowledge and students' prior knowledge, experiences, and real-world contexts. This dimension is particularly relevant to vocational education because vocational students routinely encounter practical situations that can become authentic sources for academic inquiry. Instead of asking students to write about abstract topics disconnected from their experiences, meaningful learning allows students to transform practical activities, vocational projects, workplace observations, or local problems into subjects for investigation and scientific communication. Research on meaningful learning has shown that learning becomes more powerful when students can connect academic content with experiences and contexts that they perceive as relevant (González-Ceballos et al., 2021).

The *mindful* dimension emphasizes conscious attention, metacognitive awareness, reflection, and purposeful engagement in learning. This principle is particularly important in scientific writing because students need to become aware of how they construct an argument, select evidence, organize ideas, and evaluate the quality of their own writing. Scientific writing requires learners to ask not only "What should I write?" but also "Why am I making this claim?", "What evidence supports it?", "Is the evidence sufficient?", and "Does my conclusion logically follow from the evidence?" Such questions transform writing into a metacognitive activity. The emphasis on self-monitoring and reflection is consistent with research demonstrating the importance of self-regulated strategies in academic writing (Rogers et al., 2020; Sanders et al., 2021).

The *joyful* dimension, meanwhile, recognizes that cognitive engagement cannot be separated entirely from students' emotional and motivational experiences. Learning environments characterized by meaningful participation, interaction, autonomy, and positive emotional engagement may encourage students to persist when confronting complex tasks. Recent research on joyful learning suggests that enjoyable and interactive learning experiences can contribute to student engagement and higher-order thinking when joy is integrated with cognitively purposeful activities rather than treated simply as entertainment (Hidayah & Bakhtiar, 2022; Zahro et al., 2025). Thus, joyful learning should not be conceptualized as reducing academic rigor; instead, it can create an affective environment that supports students' willingness to engage with cognitively demanding tasks.

Recent scholarship has begun to examine the integration of these three dimensions as a coherent deep-learning framework. Andayanie et al. (2025) describe deep learning as a pedagogical orientation aimed at creating learning experiences that are mindful, meaningful, and joyful, while recent literature reviews similarly emphasize the potential of integrating the three dimensions to strengthen engagement, contextual understanding, and reflective learning (Azzahra & Jaya, 2025; Feriyanto & Anjariyah, 2024). Importantly, emerging research also identifies a challenge: meaningful and joyful dimensions are often easier to observe in classroom practice, whereas mindful learning—particularly systematic reflection and metacognitive regulation—tends to receive less explicit attention. This suggests that deep learning should not be reduced to making learning enjoyable or contextual; its distinctive contribution lies in integrating engagement with conceptual depth and reflective awareness.

Despite the growing literature, several important gaps remain. First, much of the recent literature on deep learning in Indonesia remains conceptual, literature-based, or focused on broad pedagogical transformation rather than empirical investigation of specific disciplinary learning tasks. Recent studies have discussed the integration of mindful, meaningful, and joyful learning at the level of educational philosophy, curriculum, or general classroom practice (Andayanie et al., 2025; Feriyanto & Anjariyah, 2024; Somantri & Yuniarti, 2024). Consequently, there remains limited empirical evidence concerning how the three principles can be operationalized across the stages of a complex literacy task such as scientific writing.

Second, existing studies on writing instruction tend to examine particular instructional strategies—such as project-based learning, contextual learning materials, writing strategies, digital tools, or text-structure instruction—rather than examining scientific writing through an integrated deep-learning framework. The extensive writing literature demonstrates that these strategies can improve writing performance, but it does not necessarily explain how mindful engagement, meaningful contextualization, and joyful participation can operate simultaneously throughout the writing process (Graham et al., 2023; Graham et al., 2024). This distinction constitutes an important theoretical and pedagogical gap.

Third, the educational level and context of previous research remain uneven. A substantial proportion of research on academic writing has been conducted in higher education, while studies in secondary education frequently focus on general writing skills rather than scientific writing as a form of disciplinary knowledge construction. Moreover, vocational education has distinctive pedagogical characteristics because students' learning is expected to connect academic knowledge with practical competencies and occupational contexts. Consequently, the implementation of deep learning in scientific writing among vocational high school students warrants specific empirical investigation rather than being assumed to operate in the same way as in general academic education.

The present study addresses these gaps by examining the implementation of a deep-learning approach in scientific writing instruction among Grade 11 students at an Indonesian vocational high school. Rather than treating deep learning as a general pedagogical slogan, this study conceptualizes it as an integrated instructional process involving three mutually reinforcing dimensions: mindful learning, through conscious attention, reflection, self-monitoring, and evaluation of the writing process; meaningful learning, through the connection between scientific writing tasks, students' prior knowledge, vocational experiences, and authentic problems; and joyful learning, through collaborative interaction, active participation, supportive feedback, and learning activities that cultivate positive engagement.

The novelty of this study therefore lies not simply in applying "deep learning" to writing instruction, but in operationalizing the three dimensions of deep learning across the entire scientific writing process. The approach moves from identifying an authentic problem, exploring and evaluating information, formulating research questions, organizing evidence, constructing arguments, drafting scientific texts, receiving feedback, revising the text, and reflecting on the learning process. In this framework, writing becomes both a literacy outcome and a mechanism for knowledge construction. The vocational context further strengthens the meaningful dimension because students' practical experiences become resources for generating scientific questions and constructing evidence-based explanations.

This integrated perspective is important because the three dimensions address different but complementary barriers to scientific writing. Meaningful learning addresses the problem of disconnection between academic writing and students' lived or vocational experiences. Mindful learning addresses the problem of superficial engagement by encouraging students to monitor and reflect on their reasoning and writing processes. Joyful learning addresses motivational and affective barriers by creating a learning environment in which students are willing to participate actively in cognitively demanding activities. The integration of these dimensions therefore provides a potentially stronger pedagogical foundation than implementing any one dimension in isolation.

Accordingly, this study aims to examine how a deep-learning approach integrating mindful, meaningful, and joyful learning is implemented in scientific writing instruction among Grade 11 students in an Indonesian vocational high school. More specifically, the study seeks to understand how the approach shapes students' engagement with scientific writing, how vocational experiences are transformed into sources of academic knowledge, and how reflective and enjoyable learning experiences are incorporated into the writing process. By situating deep learning within the specific pedagogical demands of scientific writing and vocational education, the study contributes to the emerging empirical literature on deep learning while extending research on adolescent writing instruction beyond conventional skill-based and product-oriented approaches.

The study is expected to make two contributions. Theoretically, it contributes to the emerging conceptualization of deep learning by demonstrating how mindful, meaningful, and joyful learning can be integrated within a complex literacy practice rather than treated as separate classroom techniques. Pedagogically, it provides an empirically grounded reference for vocational teachers seeking to design scientific writing instruction that connects academic literacy with authentic vocational experiences while simultaneously fostering reflection, engagement, and deeper understanding. In this sense, scientific writing is positioned not merely as an assessment product, but as a pedagogical space in which students learn to inquire, reason, construct knowledge, and communicate evidence-based ideas.

## METHOD

### Research Design

This study employed a qualitative interpretive descriptive design to examine how a deep-learning approach was implemented in scientific writing instruction among Grade 11 students at a vocational high school in Indonesia. A qualitative design was considered appropriate because the study sought to understand the instructional process, participants' experiences, interactions, and the meanings they attributed to learning activities rather than to measure the effectiveness of the intervention statistically. The study was situated within an interpretivist paradigm, which assumes that educational phenomena are socially constructed through interactions among teachers, students, learning materials, and the instructional context. The study was further informed by a hermeneutic perspective, particularly in interpreting how meanings were constructed through classroom interactions, students' written texts, teacher reflections, and participants' accounts. Accordingly, the analysis moved beyond a descriptive account of classroom activities to examine how the principles of *mindful*, *meaningful*, and *joyful* learning were enacted and experienced during scientific writing instruction. The interpretive orientation was also used to examine discrepancies between intended instructional practices, observed classroom practices, and participants' perceptions.

### Research Setting and Context

The research was conducted at UPTD SMK Negeri Rea Timur, Polewali Mandar Regency, West Sulawesi, Indonesia, over a three-month period from May to July 2026. The school was selected purposively because scientific writing was included in the Grade 11 Indonesian language curriculum and the school provided an appropriate vocational context for examining the relationship between deep-learning principles and academic literacy. The vocational context was particularly relevant because students were expected to develop academic literacy alongside competencies associated with vocational learning. Scientific writing activities therefore provided an opportunity to examine how students transformed classroom knowledge, practical experiences, observations, and vocationally relevant issues into structured academic texts. The unit of analysis was the implementation process of the deep-learning approach in scientific writing instruction. The phenomenon was examined across classroom activities, teacher–student interactions, students' engagement with writing tasks, reflective activities, and the development of students' scientific texts.

### Participants and Sampling

Participants were recruited using purposive sampling based on their direct involvement in the learning process and their capacity to provide information relevant to the research objectives. The primary informant was the Indonesian language teacher responsible for Grade 11 scientific writing instruction. Students who directly participated in the learning activities were also included as student participants.

Participant selection followed three criteria: (1) direct involvement in the implementation of scientific writing instruction; (2) willingness and ability to describe their learning experiences; and (3) relevance of their experiences to at least one of the three deep-learning dimensions—*mindful*, *meaningful*, or *joyful* learning. Additional participants were considered when their perspectives contributed substantively to understanding the phenomenon.

Data collection continued until informational redundancy was reached, meaning that additional interviews and observations no longer generated substantively new categories or interpretations. Rather than treating saturation as a predetermined numerical target, the study used the adequacy and richness of the emerging data to determine when further data collection was no longer analytically productive.

### Data Sources and Data Collection

Data were generated through methodological triangulation involving participatory classroom observations, semi-structured interviews, and document analysis. The three sources were used not merely to corroborate factual information but to develop a more comprehensive interpretation of the phenomenon from different perspectives.

### Classroom Observation

Participatory observations were conducted during scientific writing lessons to document how the deep-learning approach was enacted in classroom practice. Particular attention was given to teacher–student interactions, instructional sequences, student participation, questioning, collaborative activities, reflection, feedback, and the use of authentic or contextual learning experiences. The observation framework was organized around the three dimensions of deep learning. The *mindful* dimension included indicators such as students' attention to learning goals, awareness of the writing process, self-monitoring, questioning, and reflection. The *meaningful* dimension focused on connections between scientific writing tasks and students' prior knowledge, practical experiences, vocational contexts, and authentic problems. The *joyful* dimension included students' emotional engagement, active participation, collaborative interaction, confidence in expressing ideas, and positive responses to learning activities. Field notes were recorded systematically during and immediately after each observation. Where appropriate and ethically permitted, classroom activities were documented through audio or visual records to support subsequent analysis.

### Semi-Structured Interviews

Semi-structured interviews were conducted with the teacher and selected students. Interview questions were developed around the research objectives and remained sufficiently flexible to allow participants to elaborate on unexpected experiences or interpretations. Teacher interviews explored instructional planning, understanding of deep learning, strategies used to integrate *mindful*, *meaningful*, and *joyful* learning, perceptions of student engagement, difficulties encountered, and adaptations made during instruction. Student interviews explored their experiences of scientific writing, perceptions of the learning activities, connections between writing tasks and their own experiences, experiences of reflection and feedback, sources of motivation, and challenges encountered during the writing process. Interviews were conducted in Indonesian, recorded with participants' permission, transcribed verbatim, and reviewed against the original recordings to minimize transcription errors. Relevant quotations were subsequently translated into English for reporting in the international publication while preserving the intended meaning of the participants' statements.

### Document Analysis

Documents were analyzed as complementary sources of evidence concerning both the intended and enacted curriculum. The documents included teaching modules, lesson plans or instructional plans, learning materials, teacher reflection journals, assessment instruments, students' drafts and revised scientific texts, and other relevant instructional records. Document analysis focused on identifying evidence of the three deep-learning dimensions, the structure of scientific writing activities, opportunities for reflection and revision, the relationship between learning tasks and students' contexts, and changes in students' written products. Student texts were examined as learning artifacts rather than solely as products to be scored, enabling the researchers to interpret how students constructed ideas, organized arguments, used evidence, and revised their writing during the learning process.

**Research Instrument and Researcher Positioning**

In accordance with qualitative research principles, the researcher served as the primary research instrument. The researcher was directly involved in designing the inquiry, establishing relationships with participants, conducting observations and interviews, interpreting data, and developing analytical categories. To enhance consistency, the researcher used structured observation guidelines, semi-structured interview protocols, and document-analysis matrices. These supporting instruments were developed from the research questions and the conceptual dimensions of *mindful*, *meaningful*, and *joyful* learning. However, they were treated as flexible analytical guides rather than rigid measurement instruments. Researcher reflexivity was incorporated throughout the study. Field notes included not only observations of participants and classroom events but also researchers' preliminary interpretations, assumptions, and methodological decisions. Reflexive consideration was particularly important because interpretation in an interpretivist study is influenced by the researcher's interaction with the field and participants. The research team therefore revisited emerging interpretations against raw field data and participants' accounts before finalizing themes.

**Data Analysis**

Data were analyzed using the interactive model of qualitative data analysis proposed by Miles, Huberman, and Saldaña (2014). Analysis was conducted concurrently with data collection rather than being postponed until the end of fieldwork. The process involved three interconnected activities: data condensation, data display, and conclusion drawing/verification. First, during data condensation, interview transcripts, observation notes, and documents were reviewed repeatedly. Relevant segments were identified and coded according to their substantive meaning. Initial codes included, among others, reflective awareness, questioning, self-monitoring, contextual connection, prior experience, authentic task, collaborative engagement, enjoyment, motivation, feedback, writing difficulty, revision, and teacher scaffolding. Both deductive codes derived from the deep-learning framework and inductive codes emerging from the data were retained.

Second, during data display, related codes were organized into matrices and thematic displays that allowed patterns to be examined across participants, data sources, and learning episodes. Particular attention was given to convergence and divergence among classroom observations, interview accounts, and documentary evidence. This stage enabled the researchers to examine whether the intended principles of deep learning were observable in classroom practice and how participants experienced those principles.

Third, conclusion drawing and verification involved identifying relationships among categories and developing higher-order themes that explained the implementation process. Emerging interpretations were repeatedly compared with the original transcripts, field notes, and documents. Interpretations that lacked sufficient empirical support were revised or removed. The analysis therefore followed an iterative movement between data, codes, categories, themes, and the developing interpretation.

The hermeneutic perspective complemented this analytical process by encouraging interpretation of classroom events in relation to their broader context. For example, students' expressions of enjoyment were not interpreted independently from the learning task; rather, they were examined in relation to the meaningfulness of the topic, teacher support, peer interaction, and students' opportunities to exercise agency. Similarly, evidence of mindful learning was interpreted not simply from students' verbal statements but from the relationship between reflection, self-monitoring, revision, and the development of their scientific texts.

**Trustworthiness**

The credibility and methodological rigor of the study were established using the trustworthiness criteria of credibility, dependability, confirmability, and transferability.

Credibility was strengthened through triangulation across data sources and collection methods. Classroom observations were compared with teacher and student interviews and with documentary evidence. Member checking was conducted by presenting relevant interpretations to participants, particularly the teacher and selected students, to verify whether the interpretations adequately represented their experiences.

Dependability was supported through systematic documentation of the research process, including sampling decisions, observation procedures, interview protocols, coding decisions, analytical memos, and revisions to emerging interpretations. An audit trail was maintained to enable the analytical process to be examined retrospectively.

Confirmability was strengthened through reflexive documentation and repeated comparison between interpretations and the underlying empirical evidence. Interpretive claims were required to be traceable to observation records, interview statements, or documentary evidence rather than being based solely on researcher assumptions.

Transferability was addressed through detailed description of the research setting, participant characteristics, instructional context, learning activities, and implementation process. Such contextual detail allows readers to assess the extent to which the findings may be applicable to other vocational education settings with similar characteristics.

**Ethical Considerations**

The study adhered to fundamental principles of ethical educational research. Permission to conduct the research was obtained from the relevant school authorities before data collection. Participants were informed about the purpose and procedures of the study, the voluntary nature of participation, and their right to withdraw from the study without academic consequences. Because the participants included school students, appropriate parental/guardian consent and student assent were obtained where required by the applicable institutional research procedures. Participants' identities were protected through the use of pseudonyms or participant codes in research records and publications. Data were stored securely and were accessed only for research purposes. The researcher also took steps to minimize the potential influence of the research process on normal classroom activities. Observation and interview procedures were arranged to avoid unnecessary disruption to teaching and learning. All audio, visual, interview, and documentary materials were handled in accordance with the applicable institutional and ethical requirements.

**Alignment of Research Components**

The methodological structure was designed to maintain alignment between the research objective, data sources, and analytical focus. Observations primarily captured the enactment of deep-learning principles; interviews examined participants' experiences and interpretations; and documents provided evidence of the intended instructional design and learning artifacts. The integration of these sources enabled the study to examine deep learning not as an abstract pedagogical concept but as an enacted, experienced, and documented instructional process within a specific vocational education context.

## RESULT AND DISCUSSION

The findings reveal that the implementation of the *Deep Learning* approach in scientific writing instruction was characterized by a gradual shift from teacher-directed and reproduction-oriented learning toward a more reflective, contextual, collaborative, and student-centered learning process. Analysis of classroom observations, teacher and student interviews, and students' scientific writing documents identified four interconnected findings: (1) the integration of *mindful, meaningful,* and *joyful learning* in scientific writing instruction; (2) the development of students' depth of thinking and originality in scientific texts; (3) challenges and adaptive strategies during implementation; and (4) changes in students' perceptions and learning awareness.

### 1. Integration of Mindful, Meaningful, and Joyful Learning

Classroom observations indicated that the implementation of *Deep Learning* was not conducted as a single instructional technique but as an integrated learning process involving three complementary dimensions: *mindful, meaningful,* and *joyful learning*. These dimensions were visible across the stages of topic exploration, scientific inquiry, writing development, discussion, feedback, and revision. The *mindful learning* dimension was evident in the way the teacher encouraged students to become aware of the purpose and process of scientific writing before they began producing their texts. Rather than immediately providing students with a predetermined scientific-writing format, the teacher initiated learning activities by inviting students to recall and identify phenomena encountered during vocational practice, laboratory activities, field observations, and production-related activities. Students were subsequently encouraged to consider why particular phenomena were worth investigating and how their experiences could be transformed into research topics.

Classroom observations showed that this process encouraged students to articulate their initial ideas before formalizing them into scientific texts. Students were not simply instructed to select a topic; they were guided to explain the phenomenon underlying their topic, identify possible problems, and determine what information would be needed to develop their scientific writing. This process created opportunities for students to monitor their own thinking while gradually developing their research ideas. The *meaningful learning* dimension was particularly prominent in the relationship between scientific writing and students' vocational experiences. The learning activities positioned scientific writing not merely as an Indonesian language assignment but as a means of documenting and communicating knowledge derived from students' practical environments. Students were given opportunities to select objects and phenomena relevant to their respective vocational areas.

Document analysis showed that several students developed scientific writing projects based on authentic objects and experiences. Examples included investigations involving the examination of chicken blood samples and observations of catfish embryo development. These topics demonstrated that students were able to transform concrete vocational or laboratory experiences into objects of academic inquiry. The contextual nature of these activities was also reflected in classroom interactions. Students were encouraged to discuss observations, compare their experiences, identify relevant information, and connect empirical findings with concepts obtained from learning resources. Consequently, the writing process was closely connected to activities of observation and inquiry rather than being limited to reproducing information from textbooks or internet sources.

The third dimension, *joyful learning*, emerged primarily through changes in classroom interaction. Observations indicated that students were provided with opportunities to discuss ideas, ask questions, conduct peer review, receive feedback, and revise their writing in a supportive environment. The teacher responded to students' errors through constructive feedback rather than solely through corrective judgment. Appreciation for students' progress and opportunities to communicate ideas appeared to create a more open classroom atmosphere. The integration of these three dimensions produced a learning process in which students were simultaneously encouraged to be attentive to their thinking, connect learning with authentic experiences, and participate actively in classroom activities. Thus, *Deep Learning* was enacted through the interaction of cognitive, contextual, reflective, and affective dimensions rather than through a single instructional activity.

**2. Development of Students' Thinking and Scientific Writing Quality**

Analysis of students' scientific writing indicated that the implementation of *Deep Learning* was accompanied by relatively strong performance in the assessed writing products. Based on the scientific-writing assessment instrument, students' scores ranged from 80 to 85, corresponding to the *very good* category used in the study. The strongest evidence of development was found in the depth of content and originality of ideas.

Students’ scientific texts increasingly originated from phenomena that they had directly encountered through vocational practice or laboratory activities. The topics concerning chicken blood sample examination and catfish embryo development illustrate how students used empirical experiences as starting points for constructing scientific texts.

This pattern differed from a purely reproduction-oriented writing process in which students primarily collect and reproduce information from existing internet sources. The documents indicated that internet-based sources were increasingly positioned as supporting references rather than as the primary content of the students’ texts. Students incorporated information from external sources to support explanations and arguments related to phenomena that they had independently observed. The development of scientific thinking was also reflected in the organization of students’ texts. Students were able to organize their scientific papers according to the expected academic structure, including the title, abstract, introduction, theoretical framework, method, results and discussion, and conclusion. The presence of these components indicates that students developed an understanding of scientific writing as a structured process rather than as an accumulation of disconnected paragraphs.

The development of textual organization occurred through gradual teacher support. Instead of expecting students to independently produce complete scientific papers from the beginning, the teacher provided guidance at different stages of writing. Students received assistance in identifying research topics, organizing information, developing sections of the paper, and revising their drafts. This pattern of gradual support was particularly important when students encountered difficulties in translating practical experiences into formal academic language. Changes were also observed in the language dimension of students’ scientific writing. Students demonstrated increasing use of effective sentences, academic terminology, and conventions associated with scientific texts. Nevertheless, document analysis continued to identify technical weaknesses, particularly in punctuation, formatting, and some aspects of linguistic accuracy. These weaknesses were not entirely eliminated during the learning process.

Importantly, the revision process demonstrated that students were increasingly able to identify weaknesses in their own writing. Students revised portions of their texts following teacher feedback and peer review. Revisions included adjustments to sentence construction, clarification of explanations, organization of information, and correction of technical writing errors. The revision process therefore provided observable evidence that students were not simply producing a final text but were engaging in an iterative process of improving their written work. The findings further indicate the emergence of higher-order cognitive processes within scientific writing activities. Students were required to identify and analyze phenomena, select relevant information, relate empirical observations to theoretical concepts, evaluate the adequacy of their explanations, and formulate conclusions based on their findings. These processes were particularly visible in the development of the discussion and conclusion sections, which students identified as more challenging than other sections of the scientific paper.

### 3. Challenges in Implementing Deep Learning and Teachers' Adaptive Strategies

Despite the positive developments, the implementation of *Deep Learning* also revealed several challenges. The most prominent challenge concerned students' previous learning habits. Classroom observations and interviews indicated that some students were accustomed to learning through memorization and reproduction of information. Consequently, they initially experienced difficulties when required to formulate their own research ideas, investigate phenomena, construct arguments, and justify conclusions. Students experienced particular difficulty in developing the background section of their scientific papers. Rather than constructing a logical sequence from a general phenomenon to a specific research problem, some students initially tended to list information without establishing clear relationships among ideas. Similar difficulties emerged when students attempted to connect theoretical concepts with empirical findings.

Another challenge concerned variation in students' initial literacy abilities. Students did not enter the learning process with identical levels of scientific-writing competence. Some students were relatively capable of organizing ideas and locating relevant information, whereas others required more intensive guidance in understanding scientific-text structures, selecting appropriate sources, constructing academic sentences, and organizing arguments. Time constraints also emerged as an important implementation challenge. Scientific writing under a deep-learning approach required opportunities for exploration, discussion, drafting, feedback, reflection, and revision. These activities required more instructional time than conventional writing assignments focused primarily on completing a final product. The teacher therefore had to manage instructional time while maintaining opportunities for students to engage in the stages of scientific inquiry and writing.

In response to these challenges, the teacher implemented several adaptive strategies. The first was scaffolding, through which complex writing tasks were divided into smaller and more manageable stages. Students were guided progressively from identifying potential topics to formulating problems, collecting relevant information, developing arguments, drafting sections of the scientific paper, and revising their texts. The second strategy was differentiated assistance. The intensity and form of teacher support varied according to students' needs. Students experiencing greater difficulties received more direct guidance, whereas students demonstrating stronger writing competence were given greater opportunities to work independently.

The third strategy involved providing students with freedom to select research topics based on their vocational interests and experiences. This strategy strengthened the connection between students' practical knowledge and academic writing tasks. Rather than writing about topics solely because they were assigned by the teacher, students could investigate phenomena that they had encountered in their own learning environments. Digital technology also supported the implementation. The use of Google Docs facilitated collaborative writing, document sharing, commenting, and feedback. Students and teachers could review and revise texts more efficiently, while collaborative access enabled feedback to be incorporated during the writing process rather than only after the final product had been completed. These strategies indicate that the implementation of *Deep Learning* was adaptive rather than rigid. The teacher continuously adjusted the degree of support, learning activities, and technological assistance according to students' responses and difficulties.

**4. Changes in Students' Perceptions and Learning Awareness**

Interview data revealed changes in students' perceptions of scientific writing. Before the implementation of the *Deep Learning* approach, students commonly perceived scientific writing as difficult, complicated, and monotonous. Their perceptions were associated particularly with the complexity of scientific-text structures, the difficulty of generating ideas, and uncertainty regarding how to organize information into an academic text. Following the implementation of contextual and experience-based learning activities, students expressed more positive perceptions of scientific writing. Students reported that writing became more interesting when they were allowed to select research objects connected to their own practical experiences. The opportunity to investigate familiar phenomena appeared to make the writing task more concrete and easier to understand.

Students' accounts also indicated a stronger sense of ownership of the scientific writing process. When the topic originated from their own observations or vocational experiences, students demonstrated greater involvement in collecting information, discussing findings, and developing explanations. The writing task was therefore perceived less as an externally imposed academic requirement and more as an opportunity to communicate something they had actually experienced or investigated. The interview findings further indicated that students became increasingly aware of the cognitive demands involved in scientific writing. The discussion and conclusion sections were frequently perceived as the most difficult components because students were required to connect empirical findings with theoretical explanations and formulate logically supported conclusions.

This awareness represents an important change in students' understanding of scientific writing. Students increasingly recognized that producing a scientific paper required more than collecting information or arranging paragraphs according to a predetermined format. They began to perceive scientific writing as a process involving observation, analysis, interpretation, argumentation, and revision. Students also identified the practical relevance of scientific writing beyond the immediate classroom task. They associated scientific-writing competence with documenting activities during vocational practice, supporting future academic study, and preparing for professional environments. Such responses indicate that students increasingly recognized the functional value of scientific literacy within and beyond school.

**5. Cross-Source Synthesis of the Findings**

Triangulation across classroom observations, interviews, and document analysis revealed a consistent pattern of change. The observational data demonstrated changes in classroom interaction, particularly through increased discussion, reflection, feedback, peer review, and teacher scaffolding. The interview data showed that students perceived scientific writing as increasingly relevant and manageable when it was connected with their practical experiences. The documentary evidence demonstrated that students produced scientific texts with scores ranging from 80 to 85 and increasingly incorporated authentic phenomena, structured arguments, academic terminology, and evidence from relevant sources. The three sources also revealed that the implementation of *Deep Learning* did not eliminate all writing difficulties. Students continued to experience challenges in academic language, punctuation, formatting, argument development, and the integration of theory with empirical findings. However, the persistence of these difficulties was accompanied by evidence of students' increasing ability to recognize and address weaknesses through revision and feedback.

Overall, the findings demonstrate that the implementation of *Deep Learning* was associated with a transformation in the process of learning to write, rather than merely an improvement in the formal characteristics of the final texts. The transformation was reflected in four interconnected patterns: students became more aware of their thinking and writing processes; scientific writing became more closely connected to authentic vocational experiences; classroom interaction became more participatory and supportive; and students increasingly viewed scientific writing as a process of inquiry and knowledge construction. These findings provide the empirical basis for interpreting *Deep Learning* as an instructional approach that operates simultaneously at the cognitive, contextual, metacognitive, and affective levels of scientific writing instruction. The theoretical implications of these findings, including their relationship to surface-to-deep learning, meaningful learning, metacognition, scaffolding, and hermeneutic interpretation of students' scientific texts, are discussed in the following section.

## DISCUSSION

The findings of this study indicate that the implementation of a *Deep Learning* approach in scientific writing instruction generated changes that extended beyond the technical improvement of students' written products. The central finding was a transformation in the learning process: students gradually moved from a predominantly reproductive orientation toward a more reflective, contextual, participatory, and knowledge-constructive mode of learning. This transformation was manifested through the integration of *mindful*, *meaningful*, and *joyful learning*, the increasing use of authentic vocational experiences as sources of scientific inquiry, the development of students' scientific writing products, and changes in students' perceptions of scientific writing. The findings therefore suggest that the value of *Deep Learning* lies less in a particular teaching technique than in the way different pedagogical processes are organized to encourage students to engage cognitively, contextually, metacognitively, and affectively with scientific writing.

## Deep Learning as a Shift from Reproduction to Knowledge Construction

The first important finding concerns the transformation of students' learning orientation. At the beginning of the learning process, students tended to perceive scientific writing as a difficult academic task characterized by predetermined structures, information searching, and reproduction of existing information. During the implementation of *Deep Learning*, however, students were progressively encouraged to identify phenomena, formulate questions, connect observations with theoretical concepts, construct explanations, and revise their texts. This indicates a movement from learning as information acquisition toward learning as knowledge construction. This finding is consistent with contemporary research on writing instruction, which demonstrates that writing competence develops more effectively when students are explicitly engaged in the cognitive processes underlying composition. Graham et al. (2023) found across 406 comparisons involving more than 52,000 students that writing instruction had positive effects on students' writing and that strategy instruction, inquiry, prewriting, feedback, goal setting, peer assistance, and text-structure instruction were among the instructional practices associated with improved writing outcomes. The present findings extend this evidence by suggesting that these processes can be conceptually organized through a *Deep Learning* orientation in which students are not only taught how to produce a scientific text but are encouraged to understand why particular information, evidence, and arguments are necessary.

The findings are also consistent with Graham et al. (2020), whose meta-analysis of 56 experiments demonstrated that writing about disciplinary content can facilitate students' learning. In the present study, students' scientific writing functioned in a similar manner: writing became a mechanism through which students processed their practical experiences and reconstructed them as academic knowledge. The significance of the finding therefore lies in the reciprocal relationship between writing and learning. Students did not merely demonstrate what they already knew through writing; the act of identifying problems, organizing evidence, explaining observations, and formulating conclusions also provided a structure through which their understanding could develop. The transformation observed in this study can consequently be interpreted as a shift from product-oriented writing toward epistemic writing. In product-oriented writing, the primary goal is to complete a prescribed text. In epistemic writing, writing itself becomes a means of examining what is known, what remains uncertain, what evidence is available, and how a defensible explanation can be constructed. This distinction is particularly important in scientific writing because the quality of a paper depends not only on linguistic accuracy but also on the relationship among research questions, evidence, interpretation, and conclusions.

## Mindful Learning and the Development of Metacognitive Awareness

The second finding concerns the role of *mindful learning* in developing students' awareness of the writing process. Classroom observations showed that the teacher did not immediately require students to produce a complete scientific paper. Instead, students were first encouraged to reflect on experiences from laboratory work, field activities, production processes, and other vocational contexts. They were then guided to identify phenomena, consider possible problems, and determine what information was necessary to investigate those problems. This process is important because scientific writing requires substantial metacognitive regulation. Students need to establish goals, plan their writing, monitor the adequacy of their evidence, evaluate the coherence of their arguments, and revise their texts when weaknesses are identified. Research on self-regulated writing provides strong support for this interpretation. Hu and Yi (2020), for example, identified goal setting, knowledge activation, strategic planning, organization, monitoring, control, reflection, and reaction as interconnected components of self-regulated writing among EFL learners. Similarly, Nückles et al. (2020) conceptualized writing-to-learn from a self-regulation perspective and argued that writing activities can support learning when learners actively regulate cognitive processes while transforming knowledge into written form.

The present findings extend these studies by showing how metacognitive processes may emerge within a *Deep Learning* environment. The *mindful* dimension was not implemented as an isolated mindfulness exercise; rather, it was embedded in the academic writing process. Students were encouraged to become conscious of what they were investigating, why they were investigating it, what evidence they possessed, and how their observations could be translated into scientific explanations. In this sense, mindfulness operated as epistemic awareness—an awareness of how knowledge is produced and justified. The findings are further supported by McKeown et al. (2021), who describe Self-Regulated Strategy Development as an evidence-based framework that combines explicit academic strategy instruction with self-regulation processes across content areas. Sanders et al. (2021) similarly emphasize the importance of intensifying and individualizing self-regulation components according to learners' needs. In the present study, teacher scaffolding played a comparable role by breaking a complex scientific-writing task into smaller stages and providing support according to students' difficulties. Importantly, the findings should not be interpreted as evidence that *mindful learning* automatically produces higher-order thinking. Rather, the data suggest that mindful learning created conditions in which higher-order processes could become visible through questioning, reflection, revision, and evaluation. This distinction is methodologically important because the present study is qualitative and interpretive. The evidence supports an interpretation of emerging metacognitive engagement, but it does not justify a causal claim that *Deep Learning* independently increased students' cognitive abilities.

### Meaningful Learning and the Vocational Context

The third major finding concerns the strong role of *meaningful learning*. Among the three dimensions, meaningfulness was particularly evident because students were encouraged to develop scientific topics from experiences associated with their vocational learning.

Scientific writing was therefore connected with phenomena that students had encountered directly, including biological observations, sample examination, agricultural production, and other practical activities. This finding provides an important contribution to the literature because it demonstrates how scientific writing can be situated within the epistemic culture of vocational education. Vocational students are expected to integrate theoretical knowledge with practical competence. When scientific writing is disconnected from this practical knowledge, students may perceive it as an abstract language task. Conversely, when their practical experiences become sources of scientific questions, writing becomes a mechanism for translating tacit or experiential knowledge into explicit academic knowledge. The effectiveness of contextualization is supported by Sujiono et al. (2023), who found that contextual and multicultural learning materials were effective in improving scientific writing among university students. Their mixed-methods study involving 101 students showed significant differences in scientific-writing performance when contextual materials were used. Suprihatin et al. (2023) similarly reported that Indonesian instructional materials employing a scientific approach influenced students' psychomotor and affective outcomes in scientific writing and recommended instructional development that supports higher-order thinking.

The present study extends these findings from the level of learning materials to the experience structure of learning itself. Meaningfulness was not produced simply by providing contextual textbooks or examples. It emerged because students were allowed to select phenomena that were connected to their vocational experiences and subsequently transform those phenomena into scientific objects of inquiry. This distinction is theoretically important. It suggests that meaningful learning is not merely a property of instructional materials; it can be understood as a relationship among the learner, the learning task, prior experience, and the context in which knowledge is applied. The findings also align with research on project-based writing. Widiastuti (2023) reported significant improvement in scientific writing through project-based learning in a classroom action research study involving 30 students. Pontjowulan (2023) likewise reported improvements in scientific-writing skills among Grade 11 vocational students through project-based learning. Although the present study did not simply implement project-based learning, the findings indicate a shared mechanism: students learn writing more deeply when writing is connected to an authentic problem, investigation, and tangible intellectual product. This is also consistent with research on project-based writing in other contexts. Permatasari and Agustine (2023) found that project-based learning improved Japanese writing skills by engaging students in active individual and collaborative writing. Yuliana and Sahayu (2024) similarly examined project-based learning for writing instruction and reported improvement in students' writing performance and positive attitudes toward writing. Taken together, these studies strengthen the interpretation that meaningfulness is generated when students perceive writing as serving an authentic communicative or problem-solving purpose.

**Joyful Learning, Engagement, and Psychological Safety**

The third pillar, *joyful learning*, emerged through changes in classroom interaction. Students were provided with opportunities to discuss ideas, exchange feedback, conduct peer review, revise their texts, and communicate their arguments without excessive fear of making mistakes. The teacher's constructive feedback and recognition of students' progress contributed to a more supportive learning environment. This finding is significant because scientific writing is an inherently demanding activity. Students must expose incomplete ideas to evaluation and tolerate revision and uncertainty. If classroom interaction is overly evaluative or punitive, students may prioritize avoiding errors rather than experimenting with ideas and developing arguments. The *joyful* dimension can therefore be understood not simply as making learning entertaining, but as creating an emotionally supportive environment in which students are willing to engage with intellectually difficult tasks.

The importance of engagement is supported by Sherifi et al. (2023), who demonstrated that student engagement is closely associated with meaningful learning and can be influenced by teaching methods, learning tools, and course content. The present findings similarly indicate that engagement increased when students experienced greater opportunities for participation, collaboration, and ownership of their writing topics. Peer interaction was particularly important. Zhang et al. (2023), in a longitudinal study of EFL students' engagement with providing peer feedback in academic writing, found that engagement in giving feedback was associated with the development of academic writing knowledge and skills, deeper problem identification, more constructive solutions, and more positive feelings. Latifi (2021) also found that structured peer feedback and feedforward influenced argumentative peer-learning processes, essay quality, and domain-specific learning. These findings support the interpretation that peer review in the present study functioned as more than a social activity: it provided students with opportunities to externalize evaluative judgments and reconsider their own writing.

The findings are further consistent with Pham and Luong (2023), who found that students incorporated a substantial proportion of peer comments into writing revisions, while also relying on their own judgments when modifying texts. This is particularly relevant to the present study because students were observed revising their texts after peer and teacher feedback. Revision therefore became a site where joyful and mindful learning intersected: the supportive social environment encouraged participation, while the revision process required students to evaluate and regulate their own writing. However, joyful learning should not be interpreted as an independent motivational variable in this study. The findings instead suggest that positive emotional engagement emerged from the interaction between meaningful tasks, supportive relationships, autonomy, and opportunities for successful participation. This interpretation is consistent with contemporary conceptualizations of deep learning that position *joyful learning* as one component of an integrated pedagogical framework rather than as an isolated technique (Feriyanto & Anjariyah, 2024; Azzahra & Jaya, 2025).

**Scaffolding as the Mechanism Linking Deep Learning and Writing Development**

One of the most important findings concerns the role of teacher scaffolding. Students did not immediately demonstrate independent mastery of scientific writing. They continued to experience difficulties in selecting research ideas, constructing backgrounds, connecting theory with empirical evidence, and developing coherent discussions. The teacher responded by dividing complex writing activities into smaller stages, providing differentiated support, and gradually increasing students' independence. This finding is consistent with the broader evidence base on writing instruction. Graham et al. (2023) identified strategy instruction, prewriting, inquiry, feedback, peer assistance, and text-structure instruction as effective writing supports for students in Grades 6–12. The present study suggests that these practices may become particularly productive when they are coordinated rather than implemented as isolated techniques.

Hashey et al. (2020) similarly proposed combining Universal Design for Learning with Self-Regulated Strategy Development to address both higher-order and lower-order barriers to writing. Their framework emphasizes engagement, multiple means of representation, and strategic writing support. This is closely related to the differentiated scaffolding observed in the present study, where students received varying levels of support according to their initial abilities. The finding also corresponds with Sanders et al. (2021), who emphasize that self-regulation support may need to be intensified and individualized for learners who experience greater academic difficulties. In the present study, differentiated assistance enabled students with weaker literacy skills to participate in the same overall scientific-writing task while receiving different forms and intensities of support. This suggests that Deep Learning should not be conceptualized as a low-scaffolding pedagogical model. On the contrary, deep learning may require substantial scaffolding at the beginning of complex learning tasks. The paradox is that teacher support can initially be intensive precisely so that students can eventually become more independent. The transition from teacher guidance to student regulation is therefore an important mechanism through which deep learning can develop.

**Scientific Writing as an Epistemic and Reflective Practice**

The improvement in students' scientific writing scores, which ranged from 80 to 85, should be interpreted together with the qualitative evidence concerning the nature of their texts. The most important development was not simply the presence of the formal components of a scientific paper but the increasing relationship between authentic observations, theoretical information, and students' explanations. Students' topics concerning chicken blood-sample examination and catfish embryo development are particularly significant because they demonstrate how scientific writing can emerge from direct empirical engagement. The students were not merely reproducing generalized information from the internet. Instead, internet-based information increasingly functioned as supporting evidence for explaining phenomena they had encountered.

This finding corresponds closely with the evidence that writing can support learning through knowledge transformation. Graham et al. (2020) showed that writing about disciplinary content can facilitate learning, suggesting that writing is not merely a communication endpoint but can function as a cognitive tool for processing disciplinary knowledge. Graham et al. (2024), in a best-evidence meta-analysis, further reinforced the importance of effective writing instruction for students in Grades 6–12.

The present findings add an important qualitative dimension to this evidence. Students' scientific texts can be interpreted as traces of epistemic development. Their revisions, changes in argumentation, selection of evidence, and attempts to connect theory with observations reveal how students gradually negotiate the relationship between experience and knowledge. From a hermeneutic perspective, this is particularly important. The scientific paper is not simply a neutral product of instruction. It is a text through which students reinterpret their experiences and give them a more systematic form. The process therefore involves movement from experience to interpretation and from interpretation to textual representation. In Ricoeurian terms, the text acquires a degree of autonomy from the original experience while simultaneously opening new possibilities for interpretation. In the present context, students' practical experiences become transformed into scientific descriptions, explanations, and arguments. The hermeneutic interpretation therefore strengthens rather than replaces the pedagogical explanation. The findings suggest that deep learning occurs when students are given opportunities to move repeatedly between experience, reflection, textualization, feedback, and reinterpretation. Scientific writing becomes the medium through which this movement is made visible.

**Peer Feedback and Revision as Sites of Deep Learning**

Another important finding is the role of revision. Students did not simply submit an initial draft as a final product. Instead, they received feedback, discussed their writing, identified weaknesses, and revised portions of their texts. This process is especially important because revision is one of the clearest observable indicators that students are reconsidering their ideas rather than merely reproducing information. The finding is strongly supported by research on peer feedback. Dong et al. (2023) conceptualized peer-feedback literacy as involving not only the ability to receive feedback but also the capacity and disposition to provide feedback. Their validation study identified knowledge and abilities, cooperative learning ability, appreciation of peer feedback, and willingness to participate as important dimensions. Usher (2023) similarly demonstrated that self-regulating writers do not simply accept all peer feedback; rather, they selectively interpret feedback and adapt their subsequent writing approaches.

This distinction is important for understanding the present findings. Students' revision should not be interpreted merely as compliance with teacher corrections. Revision represents a deeper learning process when students evaluate feedback, decide whether it is relevant, and use it to reconsider the adequacy of their arguments. Thus, peer review and teacher feedback can operate as mechanisms of *mindful learning* when students actively interpret and act upon the feedback. The findings also suggest that *joyful* and *mindful* dimensions can converge through collaborative revision. A supportive classroom environment reduces the interpersonal risks associated with exposing unfinished work, while reflective revision requires students to critically evaluate that work. This interaction may explain why students gradually became more willing to discuss weaknesses in their writing.

**Challenges as Evidence of the Complexity of Deep Learning**

The challenges identified in this study are also theoretically significant. Students' initial dependence on memorization, difficulties in formulating research questions, differences in literacy ability, and limited instructional time demonstrate that deep learning cannot be implemented simply by changing classroom activities. It requires changes in students' learning habits and teachers' pedagogical practices. This finding is consistent with recent literature on the implementation of deep learning in educational contexts. Feriyanto and Anjariyah (2024) describe the integration of meaningful, mindful, and joyful learning as requiring a transformation in how learning is organized rather than the addition of isolated classroom activities. Azzahra and Jaya (2025) similarly identify teacher capacity, conventional teaching practices, and contextual implementation as important challenges in translating deep-learning principles into classroom practice. Somantri and Yuniarti (2024) likewise conceptualize the integration of *mindful, meaningful,* and *joyful* learning as part of a broader pedagogical transformation.

The present study adds empirical detail to this emerging literature by showing how these challenges appear specifically in scientific writing instruction. The difficulty is not merely that students lack writing skills; rather, students must simultaneously learn to formulate problems, evaluate information, reason from evidence, organize academic discourse, and regulate their own writing processes. These demands explain why deep learning requires more instructional time than conventional assignment-based writing. The challenge of time is therefore not necessarily evidence of inefficiency. It may instead reflect the greater cognitive and metacognitive demands of the approach. Deep learning requires time for students to move through cycles of inquiry, interpretation, drafting, feedback, revision, and reflection. Attempts to compress these processes into short instructional sequences may preserve the appearance of deep learning while reducing its actual cognitive depth.

**Theoretical Contribution: Toward an Integrated Model of Deep Learning in Scientific Writing**

The central theoretical contribution of this study is the proposition that *mindful, meaningful,* and *joyful learning* should not be treated as three independent characteristics of good teaching. The findings suggest that the three dimensions operate through a mutually reinforcing relationship. Meaningful learning provides the epistemic starting point by connecting scientific writing with students' vocational experiences. Mindful learning provides the regulatory mechanism through which students examine, organize, monitor, and revise their developing knowledge. Joyful learning provides the affective-social condition that enables students to participate, take intellectual risks, collaborate, and persist through revision. When these dimensions converge, scientific writing becomes a process of knowledge construction rather than a purely formal language exercise. This interpretation extends the emerging literature on pedagogical deep learning. Existing Indonesian scholarship has increasingly framed deep learning around the integration of *mindful, meaningful,* and *joyful* learning, but much of this literature remains conceptual or review-based (Feriyanto & Anjariyah, 2024; Azzahra & Jaya, 2025). The present study contributes empirical insight by showing how the three dimensions can be operationalized within a complex disciplinary literacy activity.

The findings also suggest a process model:

Authentic vocational experience → mindful problem identification → meaningful inquiry → collaborative knowledge construction → scientific drafting → feedback and revision → reflective reinterpretation → scientific text.

This sequence is not proposed as a universal instructional model, but as an interpretive representation of the learning process observed in this study. Its significance lies in demonstrating that deep learning can be understood as iterative movement between experience and abstraction. Students begin with concrete experience, transform experience into questions, connect questions with theoretical knowledge, construct written interpretations, receive responses from others, and then reinterpret their own work through revision. Such a process is particularly appropriate for vocational education because vocational knowledge itself is located at the intersection of theory and practice. Scientific writing can therefore function as a bridge between these domains.

**Implications for Vocational Education**

The findings have several pedagogical implications. First, scientific writing instruction in vocational schools should not be separated from students' practical learning. Teachers can use laboratory observations, production activities, field practice, workplace simulations, and vocational projects as starting points for scientific inquiry. Second, teachers should design writing instruction as a process rather than a single assignment. Students should be provided with structured opportunities for topic generation, inquiry, drafting, feedback, revision, and reflection. The evidence from Graham et al. (2023, 2024) strongly supports the value of process-oriented and strategically supported writing instruction for secondary students. Third, scaffolding should be gradually differentiated. Students with weaker initial writing competence may require explicit modeling and more intensive support, whereas more proficient students can be given greater autonomy. This principle is consistent with research on self-regulated strategy development and differentiated writing support (Hashey et al., 2020; McKeown et al., 2021; Sanders et al., 2021).

Fourth, peer review should be structured rather than merely added to the lesson. Students need explicit criteria for evaluating arguments, evidence, organization, and clarity. This is important because peer feedback becomes pedagogically meaningful when students learn how to provide, interpret, and use feedback rather than simply exchange comments (Dong et al., 2023; Zhang et al., 2023). Finally, digital platforms such as collaborative document systems can support the iterative nature of scientific writing. However, technology should remain subordinate to pedagogy. The critical mechanism is not the digital platform itself but whether technology facilitates inquiry, collaboration, feedback, revision, and reflection.

**Limitations and Directions for Future Research**

Several limitations should be considered when interpreting these findings. First, the study was conducted in a single vocational high school and focused on a specific Grade 11 learning context. Consequently, the findings should be transferred cautiously to other schools, vocational programs, or educational systems. Second, the qualitative design provides rich information about processes and meanings but does not establish causal effects of *Deep Learning* on writing performance. Third, although students' scientific writing scores ranged from 80 to 85, the study did not employ a controlled pretest–posttest design. Therefore, the observed writing quality should not be interpreted as definitive evidence that *Deep Learning* caused an improvement in writing ability. Fourth, the interpretation of *mindful*, *meaningful*, and *joyful learning* was mediated by the researcher's interpretive position. Although triangulation and member checking strengthened credibility, alternative interpretations remain possible.

Future research should therefore examine the framework using mixed-methods or longitudinal designs. Quantitative studies could investigate changes in scientific-writing performance, metacognitive awareness, engagement, and writing self-efficacy, while qualitative studies could examine how these changes develop over longer periods. Comparative studies across vocational and general secondary schools would also be valuable for determining whether the vocational-context mechanism identified in this study is transferable. Future research could additionally investigate how artificial intelligence and digital writing tools interact with *mindful*, *meaningful*, and *joyful* learning without replacing students' own epistemic work.

**Overall Interpretation**

Taken together, the findings indicate that the contribution of *Deep Learning* to scientific writing lies not primarily in making writing easier, but in changing what students do cognitively and socially while writing. Students were encouraged to begin with experiences, interrogate those experiences through questions, connect them with theoretical knowledge, construct explanations, receive feedback, revise their texts, and reflect on the resulting knowledge. This process explains why the implementation produced changes not only in the formal quality of students' scientific papers but also in their perceptions of writing and their awareness of writing as a process of inquiry. The study therefore positions *Deep Learning* as an integrated pedagogical orientation in which meaning provides relevance, mindfulness provides cognitive regulation, and joy provides engagement and persistence. When these dimensions are combined with explicit writing instruction and adaptive scaffolding, scientific writing can become a powerful medium for developing students' capacity to transform vocational experience into systematic knowledge. This represents the principal contribution of the study to the emerging literature on deep learning and scientific literacy in vocational education.

## CONCLUSION

This study indicates that implementing a *Deep Learning* approach in scientific writing instruction among Grade 11 students at UPTD SMK Negeri Rea Timur can support a shift from predominantly reproductive learning toward more reflective, contextualized, and knowledge-constructive learning. By integrating the principles of *mindful*, *meaningful*, and *joyful learning*, the approach enabled students to move beyond the acquisition of scientific writing conventions toward greater awareness of their thinking processes, stronger connections between vocational experiences and academic concepts, and the construction of arguments grounded in empirical evidence. The findings further suggest that students' authentic vocational experiences functioned as important epistemic resources for producing more original and meaningful scientific texts. Through structured discussion, *scaffolding*, peer feedback, and iterative revision, students were encouraged to interrogate their ideas, connect evidence with theoretical perspectives, and progressively refine their written arguments. However, the implementation also revealed persistent challenges, particularly students' prior orientation toward surface learning, variation in initial literacy competence, limited instructional time, and difficulties in translating empirical observations into theoretically informed arguments. Taken together, *Deep Learning* is better conceptualized not as a discrete instructional technique but as an integrated pedagogical orientation that connects authentic experience, metacognitive awareness, contextual relevance, social interaction, and reflection within the writing process. The study therefore highlights the value of designing scientific writing instruction that is contextually grounded in vocational practice and responsive to students' existing experiences, while providing sustained scaffolding to facilitate deeper forms of learning and knowledge construction.

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