Integrating Project-Based Learning and Artificial Intelligence (PjBL-AI) Model to Enhance Students' Descriptive Writing Skills

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Abstract

This study investigates the effect of integrating the Project-Based Learning model with Artificial Intelligence (PjBL-AI) on university students' descriptive writing skills. Using a quasi-experimental pretest–posttest control group design, the research involved third-semester students of the Indonesian Language and Literature Education Department at Universitas Negeri Makassar. Two classes were selected: the experimental group, which received instruction through the PjBL-AI model, and the control group, which was taught using conventional methods. Data were collected through a descriptive writing test and a student perception questionnaire on AI use, and analyzed using normality, homogeneity, Paired Sample t-test, and Independent Sample t-test analyses. The results showed that the experimental group achieved a significant 25.5% improvement in writing scores, compared to an 8.5% insignificant increase in the control group. The PjBL-AI model effectively enhanced students' content development, text organization, vocabulary, grammar, and writing mechanics. AI integration facilitated cognitive and metacognitive processes through real-time feedback, supporting the stages of planning, drafting, revising, and publishing. This study reinforces constructivist and sociocognitive theories in writing instruction, demonstrating that PjBL-AI can serve as an innovative and adaptive pedagogy that promotes digital literacy and higher-order thinking. Overall, this research introduces a novel approach to AI-assisted project-based learning and provides empirical evidence for its effectiveness, offering valuable insights for future studies and curriculum innovation in language education.

Keywords: *Project-Based Learning, Artificial Intelligence, Descriptive Writing, Writing Skills, Higher Education*

Introduction

The rapid advancement of digital technology has brought about a fundamental transformation in global education, shifting learning paradigms from conventional, teacher-centered models toward technology-based systems that are adaptive, collaborative, and learner-centered (Zawacki-Richter et al., 2019; Al-Fraihat et al., 2020). Within this transformation, writing particularly descriptive writing has become a central academic competency that reflects students' linguistic proficiency while simultaneously developing their critical thinking, creativity, and ability to construct meaning systematically (Hyland, 2022). Descriptive writing serves as a foundational skill in academic development because it enables students to describe observations, illustrate scientific phenomena, and construct evidence-based arguments (Sandstrom, 2021). Despite its significance, numerous international and national reports indicate that

students' writing proficiency remains below expectations, particularly in aspects such as coherence, linguistic accuracy, and idea development. This condition underscores the pressing need for innovative instructional models that can effectively enhance writing skills in a meaningful and sustainable manner.

In Indonesia, students' limited writing ability continues to be a primary concern in higher education. Research by Inggriyani and Pebrianti (2021) found that university students often struggle to develop descriptive paragraphs that meet linguistic and rhetorical standards, compose effective sentences, and select appropriate diction. These difficulties are often linked to low intrinsic motivation, insufficient individualized feedback, and a lack of engaging instructional design (Sari et al., 2023). Consequently, writing is frequently perceived as a mere academic obligation rather than a reflective and creative process. Such circumstances suggest that current instructional approaches have not yet successfully cultivated the motivation, autonomy, and engagement necessary for students to develop their writing competence. Therefore, a new pedagogical direction is urgently needed that integrates meaningful learning experiences with adaptive technological support.

The emergence of Artificial Intelligence (AI) provides a strategic opportunity to address these challenges through automated feedback, algorithm-based text evaluation, and personalized learning experiences. Studies by Escalante et al. (2023) and Li and Wilson (2025) have revealed that AI-based platforms, such as Grammarly and ProWritingAid, effectively improve students' grammatical accuracy, sentence cohesion, and paragraph structure through real-time feedback. Beyond functioning as a corrective tool, AI can serve as a pedagogical agent that enhances self-regulation and reflective learning (Chen, 2023). This perspective redefines AI as a digital scaffold that supports students' metacognitive engagement by providing adaptive feedback aligned with individual learning needs. Consequently, the integration of AI into writing instruction has the potential to create a more interactive, personalized, and effective learning environment that fosters sustainable improvement in students' writing abilities.

Complementing the role of AI, the Project-Based Learning (PjBL) model offers a constructivist pedagogical foundation that situates students as active agents in the knowledge construction process (Piaget, 1971; Vygotsky & Cole, 1978). PjBL emphasizes learning through authentic projects that encourage collaboration, exploration, and reflection (Thomas, 2000). Within this framework, writing is viewed not merely as a linguistic skill but as a higher-order cognitive process involving analysis, synthesis, and evaluation (Krajcik & Blumenfeld, 2005). The process writing theory, as proposed by Flower and Hayes (1981), further reinforces this view, conceptualizing writing as a recursive process that includes planning, drafting, revising, and evaluating. Meanwhile, Systemic Functional Linguistics (Halliday, 1996) underscores that language functions as a social semiotic system used to represent experience and construct meaning within cultural and situational contexts. Through the integration of PjBL and AI, students can engage in authentic, reflective, and iterative writing practices supported by intelligent feedback that reinforces both linguistic and cognitive development.

Previous studies have shown that AI-based feedback enhances linguistic accuracy and efficiency in writing (Luo et al., 2021), while PjBL improves students' motivation, creativity, and engagement (Bermudo, 2024). However, most of these studies examined the two approaches separately, focusing either on technological tools or on pedagogical design. Few have explored how AI and PjBL can function synergistically to support the process and product of writing development (Arqam & Asrifan, 2024). This reveals a theoretical and empirical gap, particularly concerning how AI-based adaptive feedback

can be embedded within project-based tasks to foster reflective, collaborative, and self-regulated learning in writing classrooms. The absence of an integrative framework that bridges constructivist pedagogy and AI-driven technology has left an open space for research innovation in higher education, especially in the field of EFL writing instruction.

Addressing this gap, the present study proposes an integrative instructional framework that combines Project-Based Learning with Artificial Intelligence (PjBL-AI) to enhance descriptive writing skills among university students. The novelty of this research lies in its unified approach, which blends the experiential and collaborative aspects of PjBL with AI's capacity to provide real-time, adaptive feedback. This integration not only supports students in producing coherent and accurate texts but also strengthens their metacognitive and reflective engagement throughout the writing process. Furthermore, this study contributes theoretically by extending constructivist and sociocognitive learning principles into a technology-enhanced environment that aligns with the digital literacy and learning preferences of Generation Z students.

Based on the rationale, this study aims to describe the implementation of the Project-Based Learning model integrated with Artificial Intelligence (PjBL-AI) in descriptive writing instruction and to identify the key components that contribute to improving students' writing skills. It also aims to examine how this integration promotes reflective learning, learner autonomy, and active engagement in digital writing environments. Through this synergy, the study aspires to develop a pedagogical model that is not only effective and adaptive but also theoretically enriching, providing a new perspective on how technology and constructivist pedagogy can jointly support writing instruction in higher education.

Method
Research Design
This study employed a quantitative approach with a quasi-experimental pretest–posttest control group design, as the research participants were already assigned to naturally formed classes, making individual randomization unfeasible. This design is widely used in contemporary educational research because it enables the comparative testing of treatment effects while maintaining internal validity through initial and final measurements (Chien et al., 2020). The experimental group received the Project-Based Learning model integrated with Artificial Intelligence (PjBL-AI), in which AI tools such as ChatGPT and Grammarly were incorporated to assist the writing process from planning to final revision. Conversely, the control group followed conventional instruction involving lectures and manual writing exercises without AI support. This comparative framework was expected to reveal the differential impact of PjBL-AI integration on students' descriptive writing skills.

Participants and Sampling
The study was conducted in the Indonesian Language and Literature Education Department at Universitas Negeri Makassar, involving third-semester students in the 2024/2025 academic year. As the students were administratively grouped into intact classes, cluster random sampling was employed, whereby existing classes rather than individual students were randomly assigned to experimental and control conditions. This approach is suitable when individual randomization is impractical, but statistical validity can still be maintained by controlling for group effects (Hemming et al., 2015). Two classes were selected: Class A, the experimental group, and Class B, the control group,

each comprising 30 students. This sample size met the minimum statistical power requirement for classroom-based quasi-experimental research, ensuring the representativeness of the population.

Variables and Operational Definitions

This study involved two variables: the independent variable was the implementation of the Project-Based Learning model integrated with Artificial Intelligence (PjBL-AI), and the dependent variable was students' descriptive writing skills. The PjBL-AI model was operationally defined as a pedagogical approach in which students function as planners, implementers, and evaluators of descriptive writing projects, supported by AI technologies that provide automated feedback, vocabulary enrichment, sentence structure suggestions, and discourse cohesion improvement (Arqam & Asrifan, 2024). Descriptive writing skills were operationalized through five dimensions: content, organization, vocabulary, grammar, and mechanics, as adapted from Mahmudi (2018).

Instruments

Two primary instruments were used to collect data: a descriptive writing test and a student perception questionnaire. The writing test was administered twice before the treatment (pretest) and after the treatment (posttest) and scored using an analytical rubric with five criteria, each rated on a scale of 1 to 5. The scoring rubric was adapted from Mahmudi (2018) to ensure construct validity. The perception questionnaire assessed students' attitudes and experiences regarding the integration of AI in writing instruction, using a 4-point Likert scale that ranged from "strongly disagree" to "strongly agree." The questionnaire was reviewed by three experts in applied linguistics and educational technology to establish content validity, which achieved an Aiken's V value above 0.80, indicating high validity. The internal consistency of the questionnaire was verified through Cronbach's Alpha testing, yielding a coefficient of 0.85, which demonstrates strong reliability. Inter-rater reliability for the writing assessment was also calculated using the method of Merriam and Tisdell (Ulum, 2016), resulting in an agreement coefficient above 0.75, which is categorized as high.

Research Procedures

The research procedure was systematically organized into three main stages: the pre-experimental stage, the experimental implementation stage, and the post-experimental stage. In the pre-experimental stage, both the experimental and control groups were administered a pretest designed to assess their initial descriptive writing ability. This step was crucial to ensure that both groups were equivalent in writing proficiency before the intervention began, allowing for a valid comparison of outcomes.

During the experimental implementation stage, the intervention was conducted over four instructional sessions, each spanning one week. The experimental group received instruction through the Project-Based Learning integrated with Artificial Intelligence (PjBL-AI) model, which was structured into five project phases: (a) project identification, (b) exploration and data gathering, (c) draft development using AI tools, (d) revision and refinement through AI-assisted feedback, and (e) presentation or publication of the final text. Throughout these stages, AI applications such as *ChatGPT* and *Grammarly* were utilized to provide immediate feedback on linguistic accuracy, sentence cohesion, and rhetorical organization. In contrast, the control group received traditional instruction that emphasized teacher explanations, guided exercises, and manual

revisions, without the use of AI support, thereby maintaining a conventional pedagogical framework.

Finally, in the post-experimental stage**,** both groups completed a posttest using the same descriptive writing assessment instrument as in the pretest. This final stage aimed to measure the extent of improvement in writing performance and to determine the effectiveness of the PjBL-AI instructional model compared to conventional teaching methods. The data obtained from these assessments were then subjected to statistical analysis to evaluate the differences in writing achievement between the two groups.

Data Analysis

All data were analyzed using SPSS version 26. Prior to hypothesis testing, data were screened to ensure compliance with parametric assumptions. Normality was tested using the Kolmogorov–Smirnov test, while homogeneity of variances was tested using Levene's test. Within-group improvement was analyzed using the Paired Sample t-test, and between-group differences in improvement were examined using the Independent Sample t-test at a significance level of 0.05. Effect sizes were also calculated using Cohen's d to determine the magnitude of treatment effects. The results of these analyses were interpreted to evaluate whether the integration of PjBL-AI significantly improved students' descriptive writing skills compared with conventional instruction.

Validity and Reliability Assurance

To ensure internal validity, both groups received equivalent instructional time, materials, and assessment procedures, differing only in the use of AI tools in the experimental group. Instructor bias was minimized by standardizing lesson plans and instructional guidelines. External validity was reinforced by conducting the study in authentic classroom settings that reflect typical higher education contexts in Indonesia. Reliability was further strengthened using validated instruments, inter-rater scoring procedures, and statistical control for group equivalence prior to the intervention.

Results
Descriptive Statistics

The study's findings reveal a clear distinction in learning outcomes between students who received instruction through the Project-Based Learning integrated with Artificial Intelligence (PjBL-AI) model and those who underwent conventional teaching methods. Based on the quasi-experimental data involving 60 third-semester students of the Indonesian Language and Literature Education Study Program at Universitas Negeri Makassar, both groups initially demonstrated comparable baseline writing abilities, as reflected in their nearly identical pretest mean scores 65.4 for the experimental group and 66.2 for the control group. This equivalence confirms that any subsequent differences in performance can be attributed to the instructional intervention rather than pre-existing skill disparities.

Following the intervention, a significant improvement was observed in the experimental group's writing performance. Their mean posttest score increased markedly to 82.1, representing a 25.5% improvement from the pretest. In contrast, the control group showed only a modest gain, with their mean score rising from 66.2 to 71.8, an increase of 8.5%. This substantial difference indicates that the PjBL-AI model was more effective in enhancing students' descriptive writing skills compared to conventional instruction.

Table 1. Mean Scores of Pretest and Posttest

Group	Pretest (M)	Posttest (M)	Improvement (%)
Experimental	65.4	82.1	25.5%
Control	66.2	71.8	8.5%

Further analysis of the score distribution reinforces this conclusion. The majority of students in the experimental group experienced notable gains ranging from 15 to 25 points, and several even achieved improvements exceeding 30 points. Conversely, most students in the control group showed limited progress, with some exhibiting minimal or no improvement at all. This consistent upward trend among the experimental group highlights the substantial positive impact of AI-supported project-based learning, which appears to promote deeper engagement, more accurate language use, and improved writing organization. Overall, the results suggest that integrating AI tools within a project-based framework significantly enhances students' writing competence and provides a more effective and interactive learning experience than traditional pedagogical approaches..

Improvement in the Experimental Group

The significant improvement in the experimental group's writing performance, as evidenced by the increase from a mean score of 65.4 to 82.1 (t = 5.23, p < 0.01), can be theoretically explained through the lens of constructivist learning theory and process writing theory. From a constructivist perspective (Piaget, 1971; Vygotsky & Cole, 1978), the PjBL-AI model facilitated active knowledge construction through authentic and collaborative learning experiences. Students in the experimental group were engaged as active participants who designed, explored, and revised their writing projects with continuous AI-assisted scaffolding. The integration of AI tools such as *ChatGPT* and *Grammarly* functioned as digital mediators within the *Zone of Proximal Development* (ZPD), enabling students to move beyond their current proficiency levels through guided feedback and interactive reflection. This aligns with Vygotsky's view that learning occurs most effectively when learners receive appropriate support that adapts to their developmental stage, enabling deeper conceptual understanding and improved writing performance.

From the students' perspective, 26 out of 30 demonstrate how AI integration supports the recursive and metacognitive nature of writing. The AI tools provided adaptive feedback throughout the stages of planning, drafting, and revising, thereby helping students to monitor their thought processes, evaluate textual coherence, and refine linguistic accuracy in real time. This continuous cycle of feedback and self-regulation strengthened students' ability to engage critically with their own writing, transforming the act of composing into a reflective cognitive process rather than a purely mechanical task. The consistent improvement across participants thus reflects the successful internalization of writing strategies that are cognitively grounded and technologically supported, in line with constructivist and sociocognitive principles that underpin the PjBL-AI model.

Comparison Between Groups

The slight and statistically insignificant improvement observed in the control group (from a mean score of 66.2 to 71.8; p > 0.05) can be interpreted through the lens of constructivist and sociocognitive learning theories, which emphasize active engagement, collaboration, and scaffolding as essential components of effective knowledge

construction. Conventional lecture-based instruction, which was employed in the control group, tends to be teacher-centered and transmission-oriented, offering limited opportunities for learners to engage in meaningful exploration or social interaction. According to Vygotsky's (1978) concept of the Zone of Proximal Development (ZPD), learning is most effective when learners are supported through guided participation and the use of mediating tools. In this case, the absence of interactive scaffolding and technological mediation limited students' ability to bridge the gap between their current and potential writing proficiency. Consequently, students' learning experiences remained procedural rather than transformative, resulting in minimal gains in descriptive writing competence.

From the perspective of Flower and Hayes's (1981) cognitive process theory of writing, the limited improvement also suggests that traditional instruction failed to adequately engage students in the recursive stages of planning, drafting, revising, and evaluating. Without real-time feedback or adaptive guidance, students lacked the metacognitive support necessary to effectively monitor and refine their writing processes. Moreover, in the absence of Systemic Functional Linguistics (Halliday, 1996)-based contextual understanding, students were not encouraged to view writing as a meaning-making act shaped by situational and social contexts. As a result, their texts tended to remain structurally simple and linguistically limited, reflecting surface-level learning rather than the development of higher-order cognitive and linguistic skills. This finding highlights the limitations of conventional instruction in creating a reflective, interactive, and contextually grounded learning environment that fosters substantial writing improvement.

Summary of Findings

Overall, the results demonstrate that the PjBL-AI model had a substantial and statistically significant impact on improving descriptive writing skills. The improvement observed in the experimental group was not only higher in magnitude but also more consistent across students. These findings align with recent empirical studies that highlight the effectiveness of integrating artificial intelligence tools within project-based learning environments to enhance academic writing performance.

Discussion

The findings of this study provide compelling evidence that integrating Project-Based Learning with Artificial Intelligence (PjBL-AI) significantly enhances students' descriptive writing performance compared to conventional instructional methods. This improvement is not only quantitatively evident, as demonstrated by the 25.5% gain in posttest scores, but also qualitatively reflected in the increased coherence, lexical precision, and rhetorical organization of students' texts. The following discussion elaborates on these findings from theoretical and pedagogical perspectives.

PjBL-AI Within the Constructivist Learning Paradigm

The significant improvement in the experimental group is consistent with previous studies that have demonstrated the effectiveness of combining constructivist-based pedagogies with technological mediation. Research by Escalante et al. (2023) demonstrated that AI-generated feedback offers immediate and context-sensitive support, enabling learners to revise their work more effectively and develop a deeper understanding of language use. Similarly, Li and Wilson (2025) confirmed that AI-

integrated scaffolding enhances learners' autonomy, creativity, and engagement by facilitating personalized feedback aligned with individual learning needs. These findings align with Vygotsky's (1978) concept of the *Zone of Proximal Development (ZPD)*, where learners achieve higher levels of performance through guided interaction with mediating tools and collaborative peers. In the context of this study, AI applications such as *ChatGPT* and *Grammarly* served as digital scaffolds, helping students bridge the gap between their current writing competence and their potential performance by providing adaptive, real-time guidance throughout the writing process.

Furthermore, the results of this study complement the findings of Bermudo (2024) and Arqam and Asrifan (2024), who emphasized that Project-Based Learning encourages active engagement, authentic inquiry, and reflective learning key characteristics of Piaget's constructivist theory. However, the current study extends these previous works by demonstrating that when PjBL is enhanced through AI technology, students not only collaborate in authentic learning contexts but also receive continuous cognitive and linguistic scaffolding. This dual form of support strengthens both social interaction and self-regulated learning, enabling students to construct meaning more effectively through iterative cycles of drafting and revision. Thus, the PjBL-AI integration operationalizes constructivist and sociocognitive principles within a digital environment, resulting in deeper conceptual understanding and improved descriptive writing performance.

Cognitive Processes and Metacognitive Regulation

The findings of this study align with previous research grounded in Flower and Hayes's (1981) cognitive process theory of writing, which emphasizes writing as a recursive activity involving planning, translating, and reviewing. Like the present study, Luo et al. (2021) and Escalante et al. (2023) reported that AI-assisted feedback systems enhance students' engagement in these cognitive stages by providing immediate, context-sensitive input on grammar, cohesion, and lexical selection. Such support allows learners to externalize and refine their thought processes during text production. The integration of AI tools, such as ChatGPT and Grammarly, in this study effectively activated students' higher-order thinking by facilitating idea generation, linguistic refinement, and syntactic accuracy, thereby promoting self-regulated learning. This aligns with Bruner's (1966) view of cognitive structuring, in which learners construct knowledge through active interaction with tools and experiences that enable continuous reflection and reorganization of understanding.

Moreover, the study corroborates findings from Li and Wilson (2025) and Arqam and Asrifan (2024), who highlighted that the combination of technological scaffolding and cognitive engagement fosters deeper learning outcomes in writing. While earlier studies primarily focused on the surface-level accuracy achieved through AI feedback, the present research extends these insights by demonstrating how AI integration within the PjBL framework cultivates *metacognitive regulation*. This process enables students to monitor their progress, identify areas for improvement, and make purposeful revisions key components of cognitive control in writing development. Hence, the PjBL-AI model not only reinforces the cognitive dimension of writing but also situates it within an active, reflective, and self-directed learning environment, offering stronger empirical support for the application of cognitive and metacognitive theories in technology-enhanced writing pedagogy.

Synergy Between PjBL and AI in Improving Writing Proficiency

The significant difference between the experimental and control groups underscores the pedagogical and theoretical strength of integrating Project-Based Learning (PjBL) with Artificial Intelligence (AI), as grounded in constructivist, cognitive, and sociocognitive theories. From the constructivist perspective (Piaget, 1971; Vygotsky & Cole, 1978), PjBL provides authentic and experiential contexts where learners actively construct knowledge through collaboration and inquiry, while AI functions as a mediating scaffold within Vygotsky's *Zone of Proximal Development (ZPD)*, offering adaptive feedback tailored to individual learning needs. This dual-scaffolding process encompassing both human and digital elements supports both collective meaning-making and personalized learning advancement. In alignment with Flower and Hayes's (1981) cognitive process theory of writing and Bruner's (1966) cognitive structuring, AI enhances students' metacognitive regulation by facilitating planning, revising, and evaluating stages of writing, thereby promoting self-reflection and linguistic precision. Moreover, within Halliday's (1996) Systemic Functional Linguistics framework, AI feedback helps students understand the functional use of language to construct meaning in a contextual context. Collectively, these theoretical foundations explain how the PjBL-AI model creates an interactive, reflective, and adaptive learning ecosystem—evidenced by the consistent improvement among 26 of 30 students—demonstrating its effectiveness in developing both cognitive and linguistic dimensions of writing.

Alignment with Sociocognitive Theory

The social dimension of learning was also visibly strengthened in the PjBL-AI environment, aligning with Vygotsky's sociocognitive theory and the principles of constructivism and Systemic Functional Linguistics (SFL). According to Vygotsky (1978), learning occurs through social interaction and mediation, where cognitive growth is facilitated by collaboration and the use of cultural tools in this case, AI functions as a digital mediator that supports learners' co-construction of knowledge. Within the constructivist framework (Piaget, 1971; Vygotsky & Cole, 1978), the project-based tasks provided authentic contexts for students to actively engage, share ideas, and collaboratively solve linguistic and rhetorical challenges. Simultaneously, from the SFL perspective (Halliday, 1996), writing is a social semiotic process where meaning is shaped through context and interaction. The combination of group collaboration and AI feedback in this study allowed students to exchange perspectives, negotiate meaning, and refine language choices in relation to communicative purpose and audience. This dynamic, interactive learning space fostered both cognitive and linguistic development, enabling students to reflect critically on their writing and develop peer- and AI-supported strategies that led to sustainable improvement in their descriptive writing competence.

Comparison with Previous Empirical Studies

The results of this study are consistent with previous findings indicating that AI-based tools significantly enhance grammatical accuracy, vocabulary development, and text cohesion (Luo et al., 2021; Escalante et al., 2023); however, this research advances the discussion by situating AI within the Project-Based Learning (PjBL) framework and grounding it in constructivist, cognitive, and Systemic Functional Linguistics (SFL) theories. Within the constructivist paradigm (Piaget, 1971; Vygotsky & Cole, 1978), the PjBL-AI model provides authentic, collaborative learning contexts that allow students to construct knowledge through inquiry, feedback, and reflection, while AI serves as a mediating scaffold that supports the *Zone of Proximal Development (ZPD)* by offering

adaptive and individualized guidance. From the cognitive process perspective (Flower & Hayes, 1981), the iterative use of AI feedback promotes planning, revising, and evaluating core elements of process-oriented writing development thus transforming writing from a static product into a reflective cognitive activity. Meanwhile, from the SFL standpoint (Halliday, 1996), AI feedback helps students recognize the functional relationships between linguistic forms and meaning in context, leading to more cohesive and contextually appropriate writing. Therefore, the integration of AI within PjBL not only aligns with theoretical frameworks that emphasize social interaction, cognitive regulation, and functional meaning-making but also demonstrates how process-based and collaborative learning can yield more sustained and comprehensive writing improvements than product-oriented approaches.

Practical and Pedagogical Implications

These findings have significant implications for higher education, particularly in the teaching of academic writing, as they reinforce the theoretical foundations of constructivism, cognitive process theory, and sociocognitive learning. Grounded in Piaget's (1971) and Vygotsky's (1978) constructivist principles, the PjBL-AI model promotes learner autonomy and creativity through authentic, inquiry-based projects that position students as active constructors of knowledge rather than passive recipients. The integration of AI aligns with Flower and Hayes's (1981) cognitive process theory, as it facilitates metacognitive engagement by providing real-time, individualized feedback that helps students plan, draft, revise, and evaluate their writing systematically. Moreover, consistent with Vygotsky's sociocognitive theory and Halliday's (1996) Systemic Functional Linguistics, AI serves as a digital mediator that supports collaboration, negotiation of meaning, and contextual awareness in writing. These theoretical underpinnings illustrate how the PjBL-AI model transforms traditional instruction into an adaptive, student-centered framework that accommodates diverse learning needs and fosters the critical, reflective, and technologically literate competencies essential for Generation Z learners in higher education.

Contribution to Theory and Future Research

Theoretically, this study strengthens the expanding discourse on the convergence of constructivist, cognitive, sociocognitive, and Systemic Functional Linguistics (SFL) frameworks within technology-enhanced learning environments. By integrating Piaget's (1971) and Vygotsky's (1978) constructivist principles, the PjBL-AI model demonstrates how knowledge is actively constructed through authentic, collaborative, and mediated experiences, with AI functioning as a digital scaffold that supports learners within the *Zone of Proximal Development (ZPD)*. Simultaneously, the model reflects Flower and Hayes's (1981) cognitive process theory of writing, emphasizing the recursive nature of planning, drafting, and revising processes, which are enhanced through adaptive AI feedback that fosters metacognitive regulation. From the sociocognitive perspective, learning in this environment becomes a socially mediated cognitive process in which collaboration and feedback facilitate the co-construction of meaning. Additionally, Halliday's (1996) SFL framework underpins the functional role of language as a meaning-making system, where AI feedback helps students understand linguistic choices in relation to social context and purpose. Collectively, these theoretical foundations position PjBL-AI as a unified, future-oriented pedagogical model that bridges theory and practice, inviting further longitudinal research into how AI-mediated feedback shapes cognitive and linguistic development across various genres of writing.

Conclusion

This study demonstrates that the integration of the Artificial Intelligence-based Project-Based Learning model (PjBL-AI) significantly enhances students' descriptive writing skills. The experimental group that participated in the PjBL-AI model showed an average improvement of 25.5%, which was substantially higher compared to the control group, which increased by only 8.5%. These findings confirm the effectiveness of PjBL-AI in consistently improving content, organization, vocabulary, grammar, and writing mechanics.

Theoretically, this improvement can be explained through constructivist, cognitivist, and socio-cognitive theories, wherein students construct knowledge through authentic experiences, social interactions, and adaptive feedback provided by AI. The integration of AI supports students' metacognitive processes in planning, drafting, revising, and evaluating texts autonomously, thereby enhancing not only their technical writing abilities but also their critical and creative thinking skills.

The practical implication of this study is that PjBL-AI can serve as a more effective writing instructional strategy in higher education, strengthening digital literacy and facilitating differentiated learning based on students' abilities. Thus, this model offers a holistic, innovative, and sustainable instructional framework, serving as a significant reference for curriculum development and future research on integrating project-based pedagogy with AI technology.

Suggestions

Based on the findings of this research, it is recommended that higher education instructors adopt the PjBL-AI model as an innovative and effective strategy to enhance students' descriptive writing skills. The integration of AI within project-based learning provides authentic learning experiences, promotes student autonomy, and facilitates metacognitive development through adaptive, real-time feedback. Therefore, universities are encouraged to provide adequate technological infrastructure and professional development programs to enable instructors to implement this model optimally across various writing-focused courses.

For future research, it is suggested to expand the investigation of PjBL-AI to different language skills and writing genres to examine its broader applicability and long-term effects on students' cognitive, creative, and digital literacy competencies. Additionally, further studies may analyze the impact of this model on diverse learner profiles and educational contexts, thereby contributing to the development of a more comprehensive framework for AI-integrated pedagogy in higher education.

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