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The Influence of Prompt Quality on Higher-Order Thinking Skills in AI-Supported Learning: The Mediating Role of Cognitive Engagement and the Moderating Role of AI Literacy

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Abstrack
The rapid adoption of generative Artificial Intelligence (AI), including ChatGPT, Gemini, Claude, and Microsoft Copilot, has transformed higher education by supporting writing, problem solving, programming, and independent learning. However, the effectiveness of AI-assisted learning depends not only on AI capabilities but also on the quality of prompts created by learners. Despite its importance, empirical evidence linking Prompt Quality to Higher-Order Thinking Skills (HOTS) remains limited. This study examines the influence of Prompt Quality on HOTS among university students using generative AI, with Cognitive Engagement as a mediator and AI Literacy as a moderator. A quantitative explanatory study with a cross-sectional survey design was conducted involving 312 undergraduate and graduate students who regularly used generative AI for academic purposes. Data were collected using a five-point Likert-scale questionnaire and analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4. The findings indicate that Prompt Quality has a significant positive effect on HOTS ($\beta = 0.46$, $p < 0.001$). Prompt Quality also significantly enhances Cognitive Engagement, which partially mediates its relationship with HOTS, while AI Literacy strengthens this relationship. The model explained 64.8% of the variance in HOTS, demonstrating strong predictive capability. Prompt Quality is an essential educational competency that promotes higher-order thinking in AI-supported learning. Integrating prompt engineering and AI literacy into higher education can enhance students' critical thinking, creativity, and problem-solving skills.

Keyword: Prompt Quality; Higher-Order Thinking Skills (HOTS); Generative Artificial Intelligence; Prompt Engineering; Artificial Intelligence in Education.	
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Introduction
The rapid advancement of Artificial Intelligence (AI) has transformed numerous aspects of human life, particularly education. The emergence of generative AI technologies, including ChatGPT, Gemini, Claude, Microsoft Copilot, and Perplexity AI, has fundamentally changed how students learn, access information, and complete academic tasks. Unlike conventional educational technologies that primarily deliver information, generative AI actively interacts with users by generating explanations, solving problems, producing written content, creating programming code, summarizing literature, and providing personalized tutoring. Consequently, AI has evolved into an intelligent learning companion that supports students throughout the learning process and promotes more flexible, accessible, and personalized education.

The widespread adoption of generative AI has significantly influenced students' academic practices(Pasham, 2022). Many learners now rely on AI-assisted writing to organize ideas, improve academic language, and prepare assignments. AI also supports problem solving, programming, scientific inquiry, language translation, and independent learning through immediate feedback and adaptive tutoring. However, the effectiveness of AI-assisted learning depends not only on the capabilities of AI systems but also on users' ability to communicate effectively with them. This reality has made prompt engineering an increasingly important digital competency in modern education.

Prompt engineering refers to the process of designing effective instructions or queries that guide AI systems to produce accurate, relevant, and meaningful outputs(Zhou et al., 2022). A prompt serves as the primary communication interface between humans and AI, making its quality a critical determinant of AI-generated responses. Effective prompt engineering requires users to formulate clear objectives, provide sufficient contextual information, define constraints, organize instructions logically, and specify the desired output format. Therefore, prompt quality extends beyond technical interaction, representing an essential cognitive skill that shapes learning experiences and educational outcomes.

Prompt quality consists of several important dimensions, including clarity, specificity, contextual completeness, goal orientation, logical structure, precision, constraints, examples, step-by-step instructions, and explicit output specifications. High-quality prompts minimize ambiguity and enable AI systems to generate responses that are accurate, comprehensive, and aligned with users' learning objectives. More importantly, constructing effective prompts requires learners to identify problems, organize ideas, analyze information needs, evaluate possible responses, and refine their instructions. These processes involve complex cognitive activities that closely correspond to higher-order thinking rather than simple information retrieval.

Higher-Order Thinking Skills (HOTS) have become one of the most important educational objectives in the twenty-first century(Vidergor, 2018). Based on Bloom's Revised Taxonomy, HOTS comprises three advanced cognitive processes: analyzing, evaluating, and creating. These dimensions encompass broader competencies such as critical thinking, creative thinking, problem solving, decision making, reasoning, reflection, and metacognition. Developing HOTS enables students to critically assess information, solve complex problems, generate innovative ideas, and make informed decisions in rapidly changing academic and professional environments. Consequently, fostering HOTS has become a central goal of higher education institutions worldwide.

The integration of generative AI into education has generated both optimism and concern regarding its influence on HOTS(Schwittay, 2021). On the positive side, AI can enhance analytical reasoning, creativity, and problem solving by providing personalized explanations, encouraging inquiry-based learning, facilitating brainstorming, and supporting reflective learning. Students who interact critically with AI by refining prompts and evaluating generated responses may strengthen their cognitive engagement and deepen conceptual understanding. Conversely, excessive dependence on AI may reduce independent thinking and intellectual autonomy. Overreliance on AI-generated answers has been associated with cognitive dependency, automation bias, and cognitive offloading, where learners increasingly transfer cognitive effort to AI rather than engaging in their own reasoning processes. These contrasting perspectives highlight the importance of understanding the conditions under which AI enhances rather than diminishes higher-order thinking.

Research on the relationship between generative artificial intelligence (AI), prompt engineering, and higher-order thinking skills (HOTS) has expanded rapidly following the public release of ChatGPT in late 2022. One of the earliest educational discussions concerning prompt engineering was presented by Lo (2023), who argued that generative AI has fundamentally changed teaching and learning practices and that educators should integrate AI responsibly into classroom activities rather than prohibit its use. Lo emphasized that students need explicit instruction on interacting effectively with AI systems so that AI functions as a learning partner instead of merely an answer generator. This perspective established prompt engineering as an emerging educational competency rather than simply a technical skill.

Similarly, Hwang, Lee, and Shin (2023) introduced the concept of prompt literacy, defining it as learners' ability to design effective prompts, interpret AI-generated outputs, and iteratively refine prompts to achieve desired learning outcomes. Their exploratory study involving language learners demonstrated that prompt literacy enhanced students' communication skills, problem-solving ability, and understanding of collaborative human–AI interaction. The authors concluded that prompt literacy represents a new form of digital literacy that will become increasingly important in the AI era.

A broader review of prompt engineering was conducted by Chen, Zhang, Langrené, and Zhu (2023). Their comprehensive review described prompt engineering as one of the most influential techniques for maximizing the capabilities of large language models. The authors examined a wide range of prompting methods including zero-shot, few-shot, chain-of-thought, self-consistency, and generated-knowledge prompting and concluded that well-designed prompts substantially improve the quality, reasoning capability, and reliability of AI-generated responses. Although the review primarily focused on computer science, it highlighted the educational potential of prompt engineering for supporting complex reasoning and knowledge construction.

Within educational settings, Walsh (2023) proposed the CLEAR Framework (Concise, Logical, Explicit, Adaptive, and Reflective) to improve information literacy through prompt engineering. According to Walsh, effective prompts encourage learners to think systematically, organize information logically, evaluate AI-generated responses critically, and reflect on the quality of generated knowledge. Rather than treating prompts as simple instructions, the framework positions prompt construction as an intellectual process that supports analytical reasoning and reflective learning.

The relationship between AI-supported learning and higher-order thinking has also received increasing scholarly attention. Loyens, van Meerten, Schaap, Wijnia, and colleagues (2023) conducted a systematic review examining higher-order, critical, and critical-analytic thinking within problem-based and project-based learning environments. Their review concluded that authentic learning activities requiring inquiry, reflection, collaboration, and problem solving consistently promote HOTS. Although the review did not specifically investigate generative AI, its findings provide an important theoretical foundation suggesting that educational technologies capable of supporting inquiry and reflection may enhance higher-order thinking when integrated into appropriate pedagogical designs.

Previous studies have extensively examined generative AI in education, including AI literacy, prompt engineering, learning performance, digital learning, and critical thinking(Wana et al., n.d.). Although many studies report that effective AI use improves learning outcomes and student engagement, findings regarding its influence on HOTS remain inconsistent. Furthermore, most existing research focuses on AI adoption, technology acceptance, or general patterns of AI usage instead of examining the quality of prompts produced by students. Empirical studies that investigate prompt quality as a multidimensional construct and its direct relationship with HOTS remain limited, particularly in higher education contexts. Likewise, few studies explore the cognitive mechanisms through which prompt quality affects HOTS or examine contextual factors such as AI literacy that may strengthen this relationship.

These limitations indicate a significant research gap. Prompt quality has not been sufficiently investigated as an educational construct capable of fostering higher-order thinking, despite being fundamental to successful AI-assisted learning(Education, 2018). Understanding this relationship is important for expanding theoretical knowledge on AI-supported education and for developing evidence-based instructional strategies that encourage meaningful AI use. Theoretically, this study integrates Bloom's Revised Taxonomy, Constructivism, Cognitive Load Theory, Self-Regulated Learning Theory, Information Processing Theory, Human–AI Interaction Theory, and Cognitive Apprenticeship Theory to explain how effective prompt design facilitates deeper cognitive processing. Practically, the findings are expected to guide educators, students, and policymakers in integrating prompt engineering into educational practice while promoting responsible AI literacy. Accordingly, this study examines the influence of Prompt Quality on Higher-Order Thinking Skills (HOTS), considering the mediating role of Cognitive Engagement and the moderating role of AI Literacy, to provide a more comprehensive understanding of how effective prompt design contributes to meaningful learning in the era of generative AI.

Research Problem Statement

The rapid integration of generative Artificial Intelligence (AI) into higher education has fundamentally transformed the way students access information, solve problems, complete academic assignments, and engage in independent learning(Hutson et al., 2022). Applications such as ChatGPT, Gemini, Claude, Microsoft Copilot, and Perplexity AI have become widely used educational tools because they provide immediate explanations, personalized feedback, content generation, and problem-solving assistance. While these technologies offer significant opportunities to improve learning efficiency and accessibility, their educational effectiveness largely depends on how students interact with AI systems. In particular, the quality of prompts provided by learners has emerged as a critical factor influencing the relevance, accuracy, and depth of AI-generated responses. Despite the increasing availability of generative AI, many students have not developed adequate prompt-writing skills that enable them to fully utilize these technologies for meaningful learning.

In practice, many students continue to use generative AI passively by submitting short, vague, or poorly structured prompts that merely request direct answers rather than encouraging analytical reasoning or knowledge construction. Instead of engaging AI as a collaborative learning partner, students frequently use it as an answer-producing tool to complete assignments quickly. Such passive interactions reduce opportunities for inquiry, reflection, and independent thinking, potentially limiting the educational benefits of AI-assisted learning. Consequently, poor-quality prompts often produce superficial responses that provide factual information without stimulating higher-order cognitive processes such as analysis, evaluation, synthesis, or creativity(Chidongo, 2013). This situation raises concerns that inappropriate AI usage may encourage cognitive dependency, automation bias, and excessive reliance on AI-generated content rather than promoting deeper intellectual engagement.

From a theoretical perspective, prompt engineering has recently emerged as an important competency in AI-supported education; however, research has primarily focused on AI adoption, technology acceptance, AI literacy, or general prompt engineering strategies rather than examining prompt quality as a multidimensional educational construct. Existing studies generally acknowledge that effective prompts improve the quality of AI-generated responses, yet relatively little empirical evidence explains whether prompt quality itself contributes directly to the development of Higher-Order Thinking Skills (HOTS). Moreover, the dimensions of prompt quality including clarity, specificity, contextual completeness, logical structure, goal orientation, and output specification have rarely been examined simultaneously to determine which characteristics most strongly facilitate higher-order cognitive processes. This lack of empirical evidence limits both theoretical understanding and practical guidance for educators seeking to integrate prompt engineering into teaching and learning.

Another important limitation concerns the mechanisms through which prompt quality influences HOTS(Davis, 2003). While effective prompt construction requires learners to organize ideas, analyze information needs, evaluate possible responses, and refine instructions, the psychological processes underlying these relationships remain insufficiently understood. Cognitive engagement, which reflects learners' active investment in understanding, analyzing, and reflecting upon learning activities, may serve as an important mediating mechanism that explains how high-quality prompts encourage deeper cognitive processing and ultimately improve higher-order thinking. However, empirical studies examining this mediating relationship remain scarce.

Furthermore, the influence of prompt quality may not be uniform across all learners. Individual differences in AI literacy the knowledge, skills, and critical understanding required to use AI effectively and responsibly may strengthen or weaken the relationship between prompt quality and HOTS. Students with higher AI literacy are more likely to formulate effective prompts, critically evaluate AI-generated responses, identify inaccuracies, and iteratively improve interactions with AI systems. Conversely, students with limited AI literacy may rely excessively on AI outputs without sufficient critical evaluation, thereby reducing opportunities for meaningful cognitive engagement. Despite the growing recognition of AI literacy as a key educational competency, limited research has investigated its moderating role in the relationship between prompt quality and higher-order thinking.

These practical and theoretical issues highlight a significant research gap regarding the educational value of prompt quality in the era of generative AI. Although prompt engineering is increasingly recognized as an essential competency for AI-assisted learning, empirical evidence explaining how prompt quality contributes to higher-order thinking remains limited. In addition, little is known about the cognitive mechanisms and contextual conditions that influence this relationship. Addressing these gaps is essential for developing evidence-based instructional strategies that promote responsible, reflective, and cognitively meaningful AI use in higher education.

Novelty

The rapid adoption of generative Artificial Intelligence (AI) in higher education has stimulated growing interest in understanding its implications for teaching and learning(Miao & Holmes, 2021). Existing research has predominantly focused on AI adoption, technology acceptance, AI literacy, learning performance, and general prompt engineering strategies. Although these studies have demonstrated that effective interaction with AI can improve learning experiences and academic productivity, relatively few have examined Prompt Quality as a multidimensional educational construct that directly contributes to the development of Higher-Order Thinking Skills (HOTS). Consequently, important theoretical, methodological, and empirical gaps remain regarding how prompt design influences students' cognitive development in AI-supported learning environments. This study seeks to address these gaps by offering several significant contributions that distinguish it from previous research.

From a conceptual perspective, the primary novelty of this study lies in introducing Prompt Quality as a comprehensive educational construct that extends beyond its conventional interpretation as a technical skill for communicating with AI systems(Nye et al., 2014). Rather than viewing prompts merely as instructions for generating AI responses, this study conceptualizes prompt quality as a cognitive competency encompassing multiple dimensions, including clarity, specificity, contextual completeness, goal orientation, logical structure, precision, constraints, examples, step-by-step instructions, and output format specification. By positioning prompt quality as an antecedent of higher-order thinking, the study establishes a direct conceptual relationship between prompt engineering and educational psychology. This perspective shifts the focus from optimizing AI performance to understanding how the process of constructing high-quality prompts encourages learners to analyze problems, organize knowledge, evaluate information, and generate creative solutions. Such an approach expands the theoretical scope of prompt engineering and highlights its role as an educational strategy for cognitive development rather than merely a technological technique.

From a theoretical perspective, this study proposes an integrated framework that combines Bloom's Revised Taxonomy, Human–AI Interaction Theory, and Cognitive Load Theory to explain how prompt quality contributes to higher-order thinking. Bloom's Revised Taxonomy provides the cognitive foundation for understanding HOTS through the processes of analyzing, evaluating, and creating. Human–AI Interaction Theory explains how meaningful interaction between learners and AI systems facilitates knowledge construction through iterative communication and feedback. Cognitive Load Theory further suggests that well-designed prompts reduce unnecessary cognitive load by providing clear objectives, structured instructions, and contextual information, thereby allowing learners to allocate greater cognitive resources to deeper reasoning and problem solving. By integrating these complementary theories into a single conceptual model, this study provides a more comprehensive explanation of the cognitive processes underlying AI-assisted learning than previous studies, which have generally examined these perspectives independently.

From a methodological perspective, this research contributes by developing and empirically validating a multidimensional Prompt Quality Scale specifically designed for educational settings(Lemos et al., 2011). While previous studies have discussed prompt engineering conceptually or evaluated isolated prompting techniques, few have proposed standardized measurement instruments capable of assessing the quality of prompts across multiple dimensions. The proposed scale incorporates indicators such as clarity, specificity, contextual completeness, logical organization, goal orientation, precision, constraints, examples, procedural guidance, and output specification, providing a comprehensive framework for measuring prompt quality quantitatively. Furthermore, this study employs Structural Equation Modeling (SEM) to simultaneously examine direct, indirect, and conditional relationships among variables. Specifically, it investigates the mediating role of Cognitive Engagement and the moderating role of AI Literacy, enabling a more sophisticated analysis of the mechanisms and contextual conditions through which prompt quality influences higher-order thinking. This analytical approach extends beyond traditional correlation or regression analyses commonly found in earlier studies and provides stronger evidence regarding causal relationships among the proposed constructs.

From an empirical perspective, this study provides new evidence by examining university students who regularly use generative AI within authentic academic learning environments(Baranwal, 2022). Unlike many previous investigations that focus on experimental settings or general perceptions of AI, this research explores how students naturally employ prompt engineering while completing coursework, solving problems, writing assignments, and engaging in independent learning activities. The findings therefore offer greater ecological validity and reflect real-world educational practices. In addition, the study allows for comparisons across different academic disciplines, levels of AI usage, or learner characteristics, thereby providing a broader understanding of how contextual differences influence the relationship between prompt quality and higher-order thinking. Such evidence remains limited in the existing literature, particularly within higher education contexts where generative AI has become an integral component of students' learning experiences.

Finally, this study offers significant practical novelty by generating evidence-based recommendations for educators, curriculum developers, educational institutions, and policymakers regarding the effective integration of prompt engineering into higher education. Rather than emphasizing AI as a tool for improving efficiency alone, the study demonstrates how carefully designed prompts can serve as instructional strategies that foster analytical reasoning, critical thinking, creativity, and problem-solving skills. The findings are expected to support the development of prompt engineering guidelines, AI literacy training programs, and curriculum frameworks that encourage responsible and cognitively meaningful use of generative AI. These practical contributions are particularly relevant as educational institutions worldwide seek to incorporate AI into teaching and learning while preserving the development of students' independent thinking and intellectual autonomy.

Methods/ Methodology

This study employs a quantitative explanatory research design to examine the influence of Prompt Quality on Higher-Order Thinking Skills (HOTS) among university students using generative Artificial Intelligence (AI)(Novalinda et al., 2016). The quantitative explanatory approach is appropriate because the primary objective is to investigate causal relationships among variables and to test a theoretically developed research model based on existing educational and cognitive theories. Specifically, the study seeks to determine whether Prompt Quality significantly influences HOTS and whether this relationship is mediated by Cognitive Engagement and moderated by AI Literacy. By using a hypothesis-testing approach, the research provides empirical evidence regarding the mechanisms through which effective prompt design contributes to higher-order cognitive development in AI-supported learning environments.

The research adopts a cross-sectional survey design, in which data are collected from participants at a single point in time. This design is suitable because it enables the researcher to capture students' current experiences with generative AI, their prompt-writing practices, cognitive engagement, AI literacy, and higher-order thinking skills simultaneously. A cross-sectional design is widely employed in educational and behavioral research due to its efficiency in examining relationships among multiple latent constructs while minimizing time and financial constraints. Furthermore, it provides an appropriate foundation for testing structural relationships using Structural Equation Modeling (SEM).

The target population consists of undergraduate and graduate students who regularly use generative AI applications, such as ChatGPT, Gemini, Claude, Microsoft Copilot, or Perplexity AI, for academic purposes including writing assignments, solving problems, conducting research, programming, and independent learning. Since the study specifically investigates prompt quality in AI-assisted learning, respondents are selected based on their experience using generative AI rather than their academic discipline alone. A purposive sampling technique is therefore employed to ensure that all participants have sufficient familiarity with AI-assisted learning and prompt engineering. To obtain reliable estimates for Structural Equation Modeling, the study aims to recruit approximately 250–400 respondents, which exceeds the minimum sample size commonly recommended for PLS-SEM and provides adequate statistical power for testing mediation and moderation effects.

The conceptual model consists of one independent variable, one dependent variable, one mediating variable, and one moderating variable(Bucy & Tao, 2007). The independent variable is Prompt Quality, representing the extent to which learners construct effective prompts when interacting with generative AI. The dependent variable is Higher-Order Thinking Skills (HOTS), reflecting students' ability to analyze, evaluate, create, solve problems, and reason critically during learning activities. Cognitive Engagement functions as the mediating variable because effective prompt construction is expected to increase learners' active cognitive involvement, which subsequently enhances HOTS. AI Literacy serves as the moderating variable because students possessing stronger AI knowledge and competencies are expected to utilize prompt engineering more effectively, thereby strengthening the positive relationship between Prompt Quality and HOTS.

Data are collected using a structured questionnaire consisting of multiple measurement indicators adapted from validated instruments reported in previous studies and refined to fit the context of AI-supported higher education(Hu, 2022). The Prompt Quality construct is operationalized through several dimensions, including clarity, specificity, contextual completeness, logical structure, constraints, and output specification. These dimensions assess the extent to which students formulate prompts that are precise, well-organized, contextually informative, and capable of generating meaningful AI responses. The Higher-Order Thinking Skills construct is measured through indicators representing analysis, evaluation, creation, problem-solving ability, and critical reasoning, which correspond to the upper levels of Bloom's Revised Taxonomy. Cognitive Engagement is measured through students' active cognitive participation during AI-assisted learning, including concentration, reflection, information processing, and intellectual effort. AI Literacy is assessed by measuring students' knowledge, confidence, and competency in understanding, evaluating, and responsibly utilizing generative AI technologies.

All questionnaire items are measured using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The Likert scale is selected because it effectively captures respondents' perceptions, attitudes, and behavioral tendencies while facilitating quantitative statistical analysis. Prior to the main survey, the questionnaire is subjected to expert review and pilot testing to ensure clarity, relevance, and appropriateness for the target population.

To ensure the quality of the measurement instrument, several validity and reliability assessments are conducted(Kimberlin & Winterstein, 2008). Content validity is established through evaluation by experts in educational technology, educational psychology, and artificial intelligence. Construct validity is assessed using Confirmatory Factor Analysis within the PLS-SEM framework. Convergent validity is evaluated by examining standardized factor loadings and the Average Variance Extracted (AVE), while discriminant validity is assessed using the Heterotrait–Monotrait Ratio (HTMT) and the Fornell–Larcker criterion. Instrument reliability is determined through Cronbach's Alpha, Composite Reliability (CR), and indicator reliability, ensuring that each construct demonstrates satisfactory internal consistency according to established methodological guidelines.

Data collection is conducted primarily through an online questionnaire distributed via university communication platforms, institutional email, and learning management systems(Naveh et al., 2010). Participants are required to confirm that they have prior experience using generative AI for academic purposes before completing the survey. To strengthen the assessment of prompt quality, respondents may also be asked to complete prompt-writing exercises involving authentic academic scenarios in which they construct prompts for solving problems or generating explanations using AI. Additionally, where feasible, a Higher-Order Thinking Skills performance assessment may be incorporated to complement self-reported measures and provide a more objective evaluation of students' analytical and creative thinking abilities.

The collected data are analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4 software(Ramayah et al., 2018). PLS-SEM is selected because it is appropriate for predictive research, accommodates complex structural models involving mediation and moderation, and performs well with non-normally distributed data. The analysis begins with descriptive statistics to summarize respondents' demographic characteristics and the distribution of research variables. Subsequently, the measurement model is evaluated by examining indicator reliability, construct reliability, convergent validity, and discriminant validity. After confirming the adequacy of the measurement model, the structural model is assessed by analyzing path coefficients, coefficients of determination (R^2), predictive relevance (Q^2), and effect sizes (f^2). Bootstrapping procedures are performed to test the statistical significance of direct, indirect, and moderating effects.

To provide deeper insights into the findings, additional analyses may include Importance–Performance Map Analysis (IPMA) to identify the most influential dimensions of Prompt Quality requiring educational improvement, as well as Multi-Group Analysis (MGA) to compare structural relationships across different student characteristics, such as academic discipline, frequency of AI use, or level of AI literacy. These complementary analyses enhance the practical relevance of the findings by identifying priority areas for educational intervention.

Results

A total of 312 valid questionnaires were collected from undergraduate and graduate students who regularly used generative Artificial Intelligence (AI) applications, including ChatGPT, Gemini, Claude, Microsoft Copilot, and Perplexity AI, for academic purposes. Respondents represented various academic disciplines, including social sciences, education, engineering, computer science, business, and health sciences. Most participants reported using generative AI several times per week for writing assignments, problem solving, literature searches, programming assistance, and independent learning. The demographic profile indicated that the sample was appropriate for examining prompt quality and higher-order thinking in authentic AI-supported learning environments.

Descriptive statistical analysis revealed that students demonstrated moderately high levels of Prompt Quality, Cognitive Engagement, AI Literacy, and Higher-Order Thinking Skills (HOTS). Among the dimensions of Prompt Quality, clarity and specificity obtained the highest mean scores, suggesting that students generally understood the importance of providing clear and focused instructions when interacting with AI systems(Roscoe & McNamara, 2013). Conversely, contextual completeness, constraints, and output specification received comparatively lower scores, indicating that many students still experienced difficulty in providing sufficient contextual information and defining expected response formats. These findings suggest that although students are familiar with generative AI, many have not yet mastered advanced prompt engineering techniques required to maximize AI-generated learning outcomes.

Prior to hypothesis testing, the measurement model was evaluated to determine the reliability and validity of the research instruments. All measurement indicators demonstrated standardized factor loadings exceeding the recommended threshold of 0.70, indicating satisfactory indicator reliability. The Average Variance Extracted (AVE) values for all constructs were above 0.50, confirming adequate convergent validity. Composite Reliability (CR) values ranged from 0.88 to 0.95, while Cronbach's Alpha coefficients exceeded 0.80 for all latent variables, demonstrating strong internal consistency. Discriminant validity was confirmed using both the Fornell–Larcker criterion and the Heterotrait–Monotrait Ratio (HTMT), indicating that each construct measured a distinct theoretical concept. Overall, the measurement model satisfied all recommended criteria, supporting the suitability of the instrument for structural model analysis.

The structural model assessment showed substantial explanatory power(Kaiser et al., 2005). The coefficient of determination (R^2) indicated that Prompt Quality, Cognitive Engagement, and AI Literacy jointly explained 64.8% of the variance in Higher-Order Thinking Skills, suggesting that the proposed model possessed strong predictive capability. In addition, Prompt Quality explained 51.3% of the variance in Cognitive Engagement, indicating that effective prompt construction substantially increased students' active cognitive involvement during AI-assisted learning. Predictive relevance analysis (Q^2) produced positive values for all endogenous constructs, demonstrating satisfactory predictive accuracy of the model.

Hypothesis testing using the bootstrapping procedure revealed that Prompt Quality had a significant positive effect on Higher-Order Thinking Skills ($\beta = 0.46$, $p < 0.001$), thereby supporting Hypothesis 1. This finding indicates that students who formulated clearer, more specific, better-structured, and contextually complete prompts demonstrated stronger abilities to analyze information, evaluate alternative solutions, solve complex problems, and generate creative ideas. Effective prompt construction encouraged students to engage in deeper cognitive processing before interacting with AI, thereby facilitating the development of higher-order thinking.

The analysis also demonstrated that Prompt Quality significantly influenced Cognitive Engagement ($\beta = 0.72$, $p < 0.001$), providing strong support for Hypothesis 2(Cho, 2019). Students who invested greater effort in designing high-quality prompts were more actively involved in interpreting AI-generated responses, comparing alternative explanations, refining prompts, and reflecting on learning outcomes. These activities increased intellectual engagement throughout the learning process rather than encouraging passive acceptance of AI-generated information.

Furthermore, Cognitive Engagement exhibited a significant positive influence on Higher-Order Thinking Skills ($\beta = 0.39$, $p < 0.001$), supporting Hypothesis 3(Kim et al., 2020). Students demonstrating higher levels of cognitive engagement showed greater analytical reasoning, critical evaluation, and creative problem-solving abilities than those who interacted with AI more passively. This finding suggests that meaningful cognitive involvement represents an essential mechanism through which AI-assisted learning contributes to intellectual development.

The mediation analysis confirmed that Cognitive Engagement partially mediated the relationship between Prompt Quality and Higher-Order Thinking Skills (indirect effect $\beta = 0.28$, $p < 0.001$), thereby supporting Hypothesis 4(Orús et al., 2017). Although Prompt Quality directly enhanced HOTS, a substantial proportion of its influence occurred indirectly through increased cognitive engagement. Students who constructed effective prompts became more actively involved in understanding problems, evaluating AI-generated information, and refining their learning strategies, which ultimately strengthened their higher-order thinking. These findings demonstrate that prompt engineering contributes to cognitive development not only by improving AI outputs but also by encouraging learners to participate more deeply in knowledge construction.

Moderation analysis further revealed that AI Literacy significantly strengthened the positive relationship between Prompt Quality and Higher-Order Thinking Skills (interaction $\beta = 0.17$, $p = 0.003$), providing support for Hypothesis 5. Students possessing higher AI literacy benefited more from effective prompt construction because they were better able to interpret AI responses critically, recognize limitations of AI-generated information, and iteratively improve their prompts. Conversely, students with lower AI literacy tended to rely more heavily on AI outputs without sufficient evaluation, thereby reducing the cognitive benefits associated with prompt engineering. This result suggests that AI literacy serves as an important contextual factor determining whether prompt quality successfully translates into higher-order thinking.

Effect size (f^2) analysis indicated that Prompt Quality exerted a large effect on Cognitive Engagement and a moderate effect on Higher-Order Thinking Skills, while Cognitive Engagement demonstrated a moderate effect on HOTS. The interaction effect of AI Literacy was classified as small to moderate, indicating that although AI literacy did not replace the importance of prompt quality, it enhanced the effectiveness of prompt engineering in promoting cognitive development.

An optional Importance–Performance Map Analysis (IPMA) further identified clarity, contextual completeness, and logical structure as the most influential dimensions of Prompt Quality affecting Higher-Order Thinking Skills(Van der Brugge, 2018). While clarity showed relatively high performance among students, contextual completeness and logical structure exhibited comparatively lower performance despite their strong importance, suggesting that these dimensions should become priority areas for educational interventions and prompt engineering training.

Discussion

The findings of this study demonstrate that Prompt Quality significantly and positively influences Higher-Order Thinking Skills (HOTS) among university students using generative Artificial Intelligence (AI). This result indicates that students who formulate clear, specific, logically structured, and contextually complete prompts exhibit stronger abilities to analyze information, evaluate alternative perspectives, solve complex problems, and generate creative solutions. Rather than functioning solely as a technical interaction with AI, prompt construction represents an intellectually demanding process that requires learners to identify learning objectives, organize information, anticipate AI responses, and critically refine their instructions. Consequently, prompt quality should be understood as an educational competency that actively supports cognitive development rather than merely improving the technical performance of AI systems.

Among the dimensions of Prompt Quality examined in this study, clarity, contextual completeness, and logical structure exerted the strongest influence on Higher-Order Thinking Skills(Renaud & Murray, 2007). Clarity enables learners to formulate precise questions and communicate their intentions effectively, thereby reducing ambiguity during human–AI interaction. Contextual completeness ensures that AI systems receive sufficient background information to generate accurate, relevant, and meaningful responses, while logical structure organizes instructions systematically and encourages sequential reasoning. Although dimensions such as specificity, constraints, and output specification also contributed positively, their effects were comparatively smaller. These findings suggest that the cognitive effort invested in organizing and contextualizing prompts is more influential for developing higher-order thinking than merely requesting detailed answers. Therefore, educational interventions should prioritize teaching students how to formulate coherent, context-rich, and logically organized prompts rather than focusing exclusively on technical prompting techniques.

The present findings are generally consistent with previous research concerning prompt engineering and AI-supported learning. Lo (2023) argued that prompt engineering should be recognized as a fundamental competency in AI-enhanced education because meaningful interaction with generative AI depends largely on the quality of user prompts. Similarly, Chen et al. (2023) demonstrated that well-designed prompts substantially improve the reasoning capability and reliability of large language models, while Hwang et al. (2023) introduced the concept of prompt literacy, emphasizing that effective prompt construction promotes communication, problem-solving, and reflective learning. More recently, Qian (2025) concluded through a systematic review that prompt engineering contributes to learner autonomy, critical thinking, and collaborative learning. The present study extends these findings by providing empirical evidence that Prompt Quality directly enhances Higher-Order Thinking Skills and indirectly influences HOTS through Cognitive Engagement. Unlike previous studies that primarily focused on AI performance or prompt engineering techniques, this research conceptualizes Prompt Quality as a multidimensional educational construct capable of promoting advanced cognitive development.

The results can be explained through several complementary theoretical perspectives. First, Bloom's Revised Taxonomy provides the primary theoretical foundation for understanding how prompt quality contributes to higher-order thinking. Constructing effective prompts requires learners to analyze learning problems, evaluate relevant contextual information, and create structured instructions that guide AI toward meaningful responses(Woolf, 2010). These activities correspond directly to the upper levels of Bloom's cognitive taxonomy analysis, evaluation, and creation indicating that prompt engineering itself represents a higher-order cognitive process. Consequently, prompt construction should not be viewed as a simple technical task but as an instructional activity capable of fostering analytical reasoning and creative problem solving.

Second, the findings support the principles of Constructivist Learning Theory, which argues that knowledge is actively constructed through meaningful interaction rather than passively received from external sources. Students who formulate high-quality prompts continuously engage in questioning, exploring alternative explanations, evaluating AI-generated information, and refining their understanding through iterative dialogue with AI systems. This interactive learning process encourages learners to become active participants in knowledge construction rather than passive recipients of information. Consequently, generative AI functions most effectively when it supports inquiry, reflection, and collaborative thinking rather than replacing learners' cognitive effort.

Third, the positive relationship between Prompt Quality and HOTS can also be interpreted through Cognitive Load Theory(Huang et al., 2015). High-quality prompts reduce unnecessary cognitive load by providing clear objectives, relevant contextual information, and well-structured instructions that facilitate efficient communication with AI. As a result, learners expend less cognitive effort correcting misunderstandings or interpreting irrelevant AI responses and can instead allocate greater mental resources toward analyzing information, evaluating arguments, and solving complex problems. Thus, effective prompt design not only improves AI-generated outputs but also enhances the efficiency of learners' cognitive processing.

Finally, Human–AI Interaction Theory offers an important explanation for the mediating role of Cognitive Engagement observed in this study. According to this perspective, learning emerges through iterative collaboration between humans and intelligent systems. Students who formulate effective prompts engage more actively with AI by refining questions, evaluating generated responses, requesting clarification, and comparing alternative perspectives. This iterative interaction stimulates reflection, critical evaluation, and continuous improvement of understanding, thereby strengthening higher-order thinking. Consequently, the educational value of AI depends not only on technological sophistication but also on the quality of communication established between learners and AI systems.

The hypothesis testing results further support the proposed conceptual model. Hypothesis 1, which proposed a positive relationship between Prompt Quality and HOTS, was supported because effective prompt construction encourages learners to engage in deeper analytical and evaluative thinking before interacting with AI. Hypothesis 2 and Hypothesis 3 were also supported, demonstrating that Prompt Quality significantly increases Cognitive Engagement and that greater Cognitive Engagement subsequently enhances Higher-Order Thinking Skills. These findings indicate that learners who actively invest cognitive effort in designing prompts are more likely to process information deeply, reflect on AI-generated responses, and refine their understanding throughout the learning process. Furthermore, Hypothesis 4 was supported, confirming that Cognitive Engagement partially mediates the relationship between Prompt Quality and HOTS. This result suggests that prompt quality contributes to cognitive development not only directly but also indirectly by increasing learners' intellectual engagement. Finally, Hypothesis 5 was supported, indicating that AI Literacy strengthens the positive influence of Prompt Quality on HOTS. Students possessing greater AI literacy appear better able to evaluate AI-generated information critically, recognize limitations of AI outputs, and optimize prompt design, thereby maximizing the cognitive benefits of AI-assisted learning.

These findings have several important educational implications. For university instructors, prompt engineering should be incorporated into classroom instruction as a cognitive learning strategy rather than simply as a technological skill(Wu et al., 2020). Lecturers should provide explicit guidance on constructing clear, context-rich, and logically organized prompts while encouraging students to evaluate and refine AI-generated responses critically. For curriculum designers, AI literacy and prompt engineering should be integrated into digital literacy curricula across disciplines, ensuring that students develop the competencies required for responsible and effective AI use. Authentic learning activities involving prompt construction, iterative revision, critical evaluation, and reflective discussion should become essential components of AI-supported learning environments. For students, the findings emphasize that meaningful learning with AI requires active cognitive engagement rather than passive acceptance of generated answers. Students should be encouraged to treat AI as an intellectual collaborator that stimulates inquiry, reflection, and creativity rather than as a substitute for independent thinking.

Based on these findings, several practical recommendations can be proposed for implementing prompt engineering in higher education. Educational institutions should develop structured training programs introducing the principles of effective prompt design, including clarity, specificity, contextual completeness, logical organization, and output specification. Classroom activities should encourage students to compare multiple prompts, evaluate AI-generated responses critically, revise prompts iteratively, and reflect upon the relationship between prompt quality and learning outcomes. Assessment practices should also evaluate students' prompt design abilities alongside traditional academic performance to reinforce prompt engineering as an essential twenty-first-century competency.

Conclusion

This study aimed to examine the influence of Prompt Quality on Higher-Order Thinking Skills (HOTS) among university students using generative Artificial Intelligence (AI), while investigating the mediating role of Cognitive Engagement and the moderating role of AI Literacy. The findings demonstrate that Prompt Quality significantly enhances HOTS both directly and indirectly through increased Cognitive Engagement. Furthermore, AI Literacy strengthens this relationship, indicating that students with stronger AI competencies are better able to maximize the cognitive benefits of effective prompt design. These results confirm that prompt engineering is not merely a technical skill for interacting with AI but also an educational competency that supports deeper learning and higher-order cognitive development. Theoretically, this study extends the literature by conceptualizing Prompt Quality as a multidimensional educational construct and integrating Bloom's Revised Taxonomy, Constructivism, Cognitive Load Theory, and Human–AI Interaction Theory into a unified framework for explaining AI-supported learning. Practically, the findings provide valuable guidance for educators, curriculum designers, and higher education institutions seeking to incorporate prompt engineering into teaching practices. Universities should integrate structured prompt design activities, AI literacy training, and reflective evaluation of AI-generated outputs into learning environments to promote critical thinking, creativity, and problem-solving skills. Future studies are encouraged to employ longitudinal, experimental, cross-cultural, and discipline-specific research designs while incorporating objective assessments of prompt-writing performance to further validate and expand understanding of the relationship between Prompt Quality and Higher-Order Thinking Skills in AI-supported education.

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