ENHANCING HIGHER-ORDER THINKING THROUGH AI CHATBOTS: A MULTI-DOMAIN STUDY

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Artificial intelligence (AI) is increasingly integrated into education, yet its role in fostering higher-order thinking skills remains underexplored (Lu et al., 2024; Putra et al., 2023). As part of educational innovation, AI-assisted learning is being explored to enhance students' cognitive engagement and problem-solving abilities. Generative AI has demonstrated potential in facilitating cognitive engagement, but empirical research on its direct impact on analytical reasoning and critical thinking is limited. While existing studies have examined AI's role in academic writing (Kim et al., 2024) and Socratic questioning (Chukhlomin, 2024), fewer investigations have considered chatbot implementations across multiple cognitive domains. This study addresses this gap by analysing how AI chatbots function as cognitive scaffolding tools to support analytical and critical thinking among students from the School of Engineering at Temasek Polytechnic.

The study examines two AI-assisted learning interventions in the subject Leadership Fundamentals. The first implementation utilises a writing-focused AI chatbot to develop reflective thinking through structured questioning, while the second integrates an AI-powered chatbot to support ethical decision-making. Developed on the Mizou platform, both implementations employ a mixed-methods approach. Pre- and post-surveys with two intervention groups to measure the chatbots' effectiveness were implemented.

The findings indicate a measurable increase in student engagement and confidence in analytical tasks, with students describing chatbots as facilitators of structured thinking rather than passive information sources. These findings align with previous research on AI's role in student interaction (Kim et al., 2024; Wang et al., 2024) and suggest that AI-driven cognitive scaffolding may support higher-order cognitive skills.

These findings point the way for educators to further explore AI-assisted learning models that align with engineering education needs (Alamri & Alharbi, 2023) and examine AI chatbots' role in developing metacognitive and higher-order thinking skills in higher education (Lim & Makany, 2023). This paper provides information for researchers interested in further exploring the impact of AI-generated prompts on student inquiry and decision-making (Koji et al., 2024).

Keywords: AI-assisted learning, educational innovation, cognitive scaffolding, higher-order thinking, personalised learning, student engagement, alternative assessment

Introduction

Higher-order thinking skills (HOTS) are essential for students to navigate the increasingly complex challenges of the 21st century workplace and society. These skills, including critical thinking, analytical reasoning, problem-solving, and ethical decision-making, are particularly crucial for engineering students who will face multifaceted technical and ethical dilemmas in their professional careers (Alamri & Alharbi, 2023). Despite this recognised importance, developing these cognitive skills within traditional educational frameworks remains challenging, often due to constraints in providing personalised guidance and constructive feedback at scale.

Recent advances in generative artificial intelligence (AI) have created new possibilities for educational interventions aimed at fostering higher-order thinking. Generative AI systems, particularly AI-powered chatbots, offer potential as cognitive scaffolding tools that can engage students in dialogue, prompt reflection, present multiple perspectives, and guide analytical processes (Wang et al., 2024). These capabilities align with educational theories emphasising the importance of cognitive engagement, dialogic learning, and structured scaffolding in developing complex thinking skills (Chukhlomin, 2024).

While research has begun to explore generative AI applications in education, most studies have focused on narrow domains such as academic writing assistance (Kim et al., 2024) or automated feedback mechanisms. Fewer investigations have examined how chatbots might function across multiple cognitive domains simultaneously, particularly for higher-order thinking

development. Additionally, questions remain about implementation strategies, effectiveness measurement, and best practices for integrating these technologies into existing curricula (Putra et al., 2023).

This study addressed these gaps by investigating the implementation of AI chatbots as cognitive scaffolding tools in two distinct but complementary scenarios within a Leadership Fundamentals course for engineering students at Temasek Polytechnic. The first implementation focused on developing reflective thinking through guided questioning, where the AI acted as a coach to help students articulate and refine their life statements, a process requiring substantial self-awareness. The second implementation targeted the analysis of multiple perspectives in ethical dilemmas, employing AI to help students systematically examine complex scenarios from various stakeholder viewpoints.

By employing a mixed-methods approach to evaluate these implementations, this study aimed to contribute to the growing body of knowledge about effective AI integration in educational contexts, particularly for higher-order thinking development. The Mizou platform, an educational chatbot system powered by generative AI, enabled the creation of pedagogically sound chatbots that scaffolded complex thinking processes while providing a safe environment for students to explore and articulate their thoughts. The study examined how structured AI interactions might enhance students' reflective capacities and ethical reasoning skills which are both crucial for engineering students who will face complex technical and ethical challenges in their professional lives.

Materials and Methods or Pedagogy

This study employed a structured approach to investigate the effectiveness of AI-powered chatbots in enhancing higher-order thinking skills among engineering students. The research framework was designed to assess two specific AI-assisted learning interventions implemented in the Leadership Fundamentals subject at Temasek Polytechnic during the April 2025 semester.

A mixed-methods design was employed to evaluate the effectiveness of the AI chatbot interventions. This approach captured both quantitative measures of skill development and qualitative insights into students' experiences. The research design built upon preliminary observations from an informal pilot conducted in October 2024, which indicated positive student reception to AI-assisted learning activities.

The study included approximately 50 first-year engineering students enrolled in Leadership Fundamentals during the April 2025 semester. The self-leadership focused course was specifically chosen because it emphasises higher-order thinking and reflective skills over content memorisation, making it an ideal context for evaluating cognitive scaffolding interventions. Participants were divided into two intervention groups, with each group experiencing one of the two chatbot applications.

Both interventions utilised the Mizou platform. Mizou was selected for several key advantages:

educational focus with features tailored to classroom implementation; privacy and security compliance with educational standards; customisability allowing educators to design chatbots with specific personalities and interaction patterns; analytics capabilities providing insights into student engagement; and accessibility through an intuitive interface that requires no technical expertise from students.

The first chatbot intervention, named "Life Purpose", was designed to develop reflective thinking through structured questioning. It guided students through a metacognitive process to articulate and refine their personal life statements. Key features included sequential prompting that gradually increased in cognitive complexity, guided questions encouraging deeper reflection, personalised feedback based on student responses, and reflection prompts connecting personal values to professional contexts. This intervention aimed to develop students' ability to engage in meaningful self-reflection, a prerequisite for articulating vision for self.

The second chatbot intervention, named "Ethics Explorer", focused on ethical decision-making by facilitating the analysis of multiple perspectives in a complex scenario. Designed as a Discussion Facilitator, this chatbot guided students through a structured ethical reasoning process using an ethical dilemma. It encouraged diverse viewpoints by consistently providing contrasting perspectives and occasionally introducing controversial angles to challenge student thinking. Rather than providing direct answers, it guided decision-making through focused questions.

The Ethics Explorer employed a scenario-based approach where students assumed the role of different stakeholders in an ethical dilemma involving technology misuse (specifically, a deepfake video scenario with significant consequences for multiple parties). Throughout the process, students were prompted to identify stakeholder concerns, propose potential actions, justify decisions with logical reasoning, prepare counterarguments, and consolidate a final position. Guiding questions such as "What are the assumptions behind this choice?" and "How does this decision affect other stakeholders?" stimulated higher-order thinking and helped students navigate the ethical complexity.

This intervention targeted students' ability to recognise and navigate complexity, consider diverse viewpoints, and engage in evidence-based reasoning which are essential components of ethical decision-making. The learning objectives focused on developing higher-order thinking skills, including understanding ethical issues, applying ethical reasoning, evaluating arguments, and developing well-reasoned justifications.

The study measured students' self-reported confidence and abilities in higher-order thinking skills following the chatbot activities to assess the quality and depth of thinking demonstrated.

The study's design was informed by several theoretical perspectives including Scaffolded Learning Theory, Bloom's Revised Taxonomy, and Ethical Reasoning Frameworks. This theoretical grounding ensured that the chatbot interventions were designed not

merely as technological tools but as pedagogically sound approaches to cognitive development.

Results

The results of the study indicated that both AI chatbot interventions had a measurable impact on students' higher-order thinking capabilities, with distinct yet complementary findings across the two implementations. Prior to the interventions, participants reported varied levels of engagement with generative AI technology, with 32% of the Life Purpose chatbot participants and 42% of Ethics Explorer chatbot participants using generative AI technology frequently for academic work. A significant majority (68% and 75% respectively) perceived generative AI to be "fairly useful" or "extremely useful" for schoolwork **[Figure 1].** This pre-existing familiarity with AI technologies likely contributed to students' ability to engage with the chatbot interfaces, as evidenced by the high proportion of participants agreeing that the chatbots were easy to use (88% for Life Purpose chatbot and 81.3% for Ethics Explorer chatbot). This technological fluency allowed students to focus on the cognitive demands of the tasks rather than navigating unfamiliar technology, creating favourable conditions for developing higher-order thinking skills.
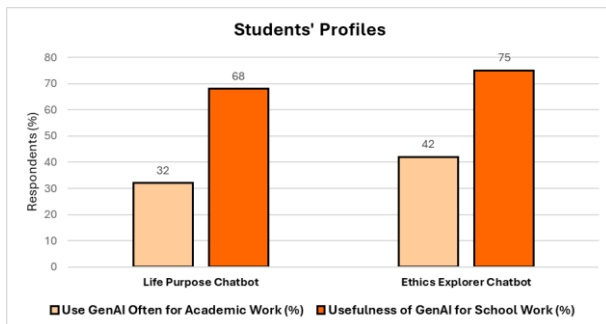

Figure 1: Students' profiles in Temasek Polytechnic

For the Life Purpose chatbot intervention, the pre- and post-intervention comparison revealed substantial improvements in students' self-reported abilities. Participants reporting high confidence (those selecting 'completely confident' or 'very confident') in completing reflective exercises doubled from 36% pre-intervention to 72% post-intervention. Similarly, the percentage of students confident in elaborating on thoughts with examples increased from 44% to 68%, while those able to critically assess their own views rose from 60% to 68%. Perhaps most notably, students confident in expressing thoughts in writing increased from 28% pre-intervention to 64% post-intervention, with 72% reporting they could write an effective Life Purpose Statement with the chatbot's assistance **[Figure 2].**
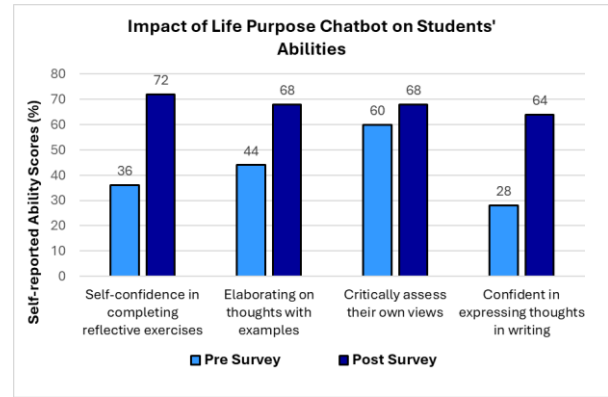

Figure 2: Students showed notable improvement across all self-reported skills

The post-intervention survey for the reflective thinking chatbot showed that 76% of respondents agreed or strongly agreed that "Using the Mizou Bot for this activity helped to enhance my ability to reflect," and 80% agreed that it helped them "structure ideas in writing better." An overwhelming 92% agreed that "The use of GenAI for this activity helped me to quickly formulate my Life Purpose Statement." When identifying cognitive skills applied during the activity, 23% indicated "analysis & reasoning," 18% selected "evaluating different perspectives/justifying a stand," and 19% noted "creating solutions/recommendations." **[Figure 3]**
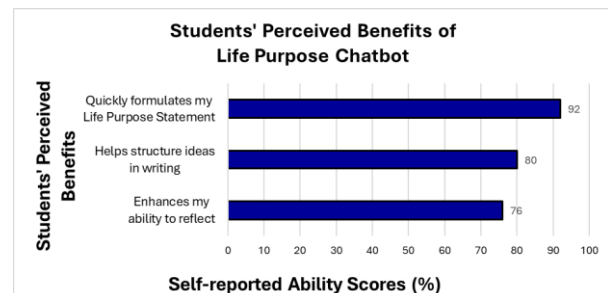

Figure 3: Students' perceived gains in reflection and idea structuring after using the Life Purpose Chatbot

For the Ethics Explorer chatbot intervention, the post-intervention survey revealed that 62.6% of respondents agreed or strongly agreed that "Using the Mizou DebateBot for this activity helped to enhance my higher-order thinking skills." More definitively, 68.8% of participants agreed that the Ethics Explorer chatbot helped them "examine different perspectives", which aligns closely with the intervention's design goal of fostering perspective-taking as a critical component of ethical reasoning. The strongest positive responses were observed regarding the chatbot's ability to scaffold argumentation and critical analysis, with 75.1% of participants agreeing or strongly agreeing that the chatbot helped them "quickly formulate arguments and counter arguments" and "examine bias and assumptions in my arguments." **[Figure 4]**
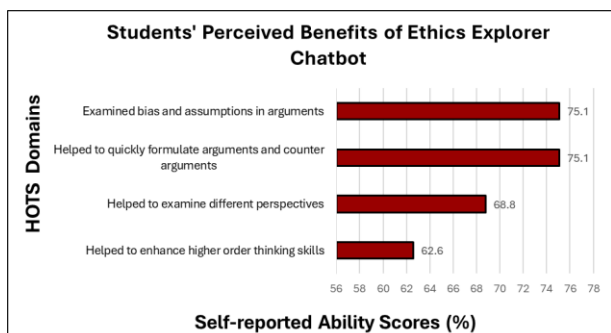
Figure 4: Students' perceived gains in reflection and idea structuring after using the Ethics Explorer Chatbot

When asked to identify the cognitive skills they applied during the activity, 81.3% of participants indicated "analysis & reasoning," and "evaluating different perspectives and/or justifying a stand," while 62.5% noted "creating or formulating solutions/ proposals/ recommendations." These responses correspond to the higher levels of Bloom's Revised Taxonomy which are analysing, evaluating, and creating.

Interestingly, whilst 75% of the Ethics Explorer chatbot participants indicated that the dialogue activity "would not have made a difference" had it been conducted without generative AI, only 24% of the Life Purpose chatbot participants shared this view. This suggests a perceived difference in utility between the two implementations. This disparity indicates that students found the reflective thinking chatbot more instrumental to completing their task than the ethical reasoning chatbot.

The qualitative responses provided deeper insights into how each chatbot facilitated higher-order thinking. For the Life Purpose chatbot, students highlighted how it helped them articulate and structure their thoughts, with comments such as "it helped me craft my life purpose statement and helped me analyse my thoughts" and "it helped me to put my ideas into a proper paragraph which encapsulated all of my points." Students particularly valued how the chatbot synthesised their inputs, with one noting it "compiled and analysed my strengths and passion which is then helped generate what would be a good future career for me." Challenges included responses that were "a bit generic" or "didn't understand me quite well."

For the Ethics Explorer chatbot, students described the chatbot as offering meaningful cognitive scaffolding through statements such as "it kept asking for even more clarification for us to work on our answer" and "it gave me different questions that I can consider." Several students highlighted perspective-taking benefits with comments such as "I was able to examine and analyse various opinions and verify different perspectives on the topic" and "Learning about the other stakeholder's opinions." The development of argumentation skills was evident in feedback like "offered me counterarguments" and "It gave me a different perspective on my statement." Some challenges were also reported, with several students finding the chatbot's responses "vague" or noting that "it didn't give me a straight answer," which aligns with the chatbot's design intention to scaffold

thinking rather than provide direct answers. When asked about ethical concepts learned, responses such as "not being biased," "be aware of consequences," and "view from different perspectives" suggested development of ethical reasoning frameworks.

Discussion

The findings align with previous research on AI's role in student interaction and educational inquiry (Kim et al., 2024; Chukhlomin, 2024). The complementary results from the two chatbot implementations demonstrate how structured AI interactions can target specific cognitive domains – reflective thinking and ethical reasoning – while engaging students across multiple levels of Bloom's Revised Taxonomy. The reflective thinking chatbot appeared particularly effective at helping students translate abstract thoughts into coherent written expressions, supporting metacognitive development. Meanwhile, the Ethics Explorer chatbot fostered critical analysis and perspective-taking essential for ethical reasoning.

The apparent difference in perceived necessity between the two chatbots suggests that technological interventions may be more valued by students when they address specific challenges, they find difficult (such as articulating complex personal reflections) compared to tasks they might feel more confident tackling independently (such as ethical discussions). This insight has implications for targeted AI implementation in educational contexts.

These findings collectively contribute to our understanding of how purpose-built AI chatbots can function as cognitive scaffolding tools that engage students in different aspects of higher-order thinking. The results suggest that carefully designed AI-facilitated dialogues can meaningfully contribute to both reflective capacity and analytical reasoning skills essential for professional development.

Conclusion

This investigation explored the potential of AI chatbots as cognitive scaffolding tools in education, with a particular focus on enhancing reflective thinking and ethical reasoning capabilities. Our findings strongly support this application: both the Life Purpose and Ethics Explorer chatbot implementations demonstrated effectiveness in strengthening their respective targeted cognitive domains.

The Life Purpose chatbot was particularly successful, enabling most students to articulate coherent personal reflections, which is a clear indication of the tool's capacity to foster deeper reflective thinking processes. Similarly, the Ethics Explorer chatbot proved valuable for developing ethical reasoning skills by facilitating students' examination of diverse perspectives and construction of well-supported arguments.

Interestingly, we observed a marked difference in how students perceived the necessity of these tools; while

three-quarters of Life Purpose chatbot users considered the AI beneficial to their learning process, only about a quarter of Ethics Explorer chatbot users viewed the chatbot as adding value to their work. This disparity suggests that students found AI assistance more valuable for personal reflection tasks and writing deliverables than for ethical reasoning exercises. This could indicate that articulating and structuring personal reflections presents a greater cognitive challenge for many students, making technological scaffolding particularly beneficial for this domain. Alternatively, it may reflect differences in how these specific chatbots were designed or implemented within their respective learning activities.

Our results contribute meaningful empirical evidence to an emerging area of research on AI-supported higher-order thinking development. Furthermore, by implementing these tools through the Mizou platform, we demonstrated how educators without specialised technical expertise can successfully incorporate AI scaffolding into their teaching practices, addressing our aim of identifying accessible and scalable educational interventions.

While our study was conducted within a specific institutional context, our approach that combines structured design methodology, theoretical grounding, and mixed-methods assessment, offers valuable insights that may inform similar AI-assisted learning initiatives in other educational settings. The experiences and perceptions captured in this exploratory study provide a practical foundation for educators interested in implementing AI chatbots as cognitive scaffolding tools.

Moving forward, we recommend that researchers expand investigation into how AI chatbots can scaffold higher-order thinking skills across additional cognitive domains and disciplinary contexts, evaluate the longitudinal impacts on student learning outcomes, and work to identify evidence-based practices for sustainable integration of these tools into higher education curricula.

Purpose-built AI chatbots, when thoughtfully designed and strategically implemented, represent a promising complement to traditional instructional approaches, supporting students' development of the reflective capacity and ethical reasoning skills that are increasingly essential for success in today's complex professional environments.

Acknowledgements

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