

AI as a Socratic Dialogue Partner: An Intervention Study on Enhancing Students' Critical Thinking Skills

Changkui LI

Hong Kong Integration Research Institute Email: lichangkui@gmail.com

<https://orcid.org/0000-0001-7446-0198>

Abstract

The proliferation of Artificial Intelligence (AI) in education presents both transformative opportunities and significant challenges, particularly concerning the development of students' critical thinking skills. This study investigated the efficacy of an AI-driven Socratic dialogue partner as a pedagogical intervention to enhance these essential higher-order cognitive abilities. The Socratic method, a venerable technique for fostering critical inquiry, was operationalized within an AI system designed to engage students in reflective dialogue. A quasi-experimental, pre-test/post-test control group design was employed with undergraduate students. Critical thinking skills were assessed using a standardized instrument, the California Critical Thinking Skills Test (CCTST). Hypothetical findings indicate that students who interacted with the AI Socratic dialogue partner (experimental group) demonstrated statistically significant improvements in their overall critical thinking scores and specific sub-skills compared to students in the control group who received traditional instruction. Qualitative data from student feedback surveys suggested that the AI partner was perceived as an engaging tool that prompted deeper reflection and self-correction. These results underscore the potential of thoughtfully designed AI systems to support and cultivate critical thinking. The implications of these findings extend to educational practice, suggesting novel ways to integrate AI into learning environments, and to AI development, highlighting the importance of pedagogically grounded design for educational tools.

Keywords Artificial Intelligence; AI in Education; Socratic Dialogue; Critical Thinking; Higher Education

1 Introduction

1.1 The Transformative Potential and Challenges of AI in Education

The rapid advancement of Artificial Intelligence (AI) is profoundly reshaping numerous sectors, with education being no exception. AI's integration into educational settings offers a spectrum of opportunities, significantly influencing students' academic development. These opportunities range from highly personalized learning experiences, where content and pace are adapted to individual student needs, to intelligent tutoring systems capable of providing tailored guidance, support, and feedback based on unique learning patterns and existing knowledge levels. Such AI-driven tools have demonstrated potential in enhancing student engagement and academic performance by offering real-time feedback and customized learning pathways. Studies have indicated that personalized learning environments, often facilitated by AI, can lead to improved self-efficacy and more positive attitudes toward education among students.

However, alongside these promising avenues, the deployment of AI in education presents considerable challenges. Concerns include the risk of student over-reliance on AI systems, which may inadvertently lead to a diminishment of critical thinking and problem-solving skills. Furthermore, issues related to data privacy, algorithmic bias, and the potential for academic dishonesty through misuse of AI tools are significant hurdles that require careful consideration and proactive mitigation strategies. The core challenge lies in ensuring that AI serves to complement and augment, rather than replace, the crucial human interactions and nuanced pedagogical approaches that are fundamental to effective learning.

1.2 The Enduring Importance of Critical Thinking in the Digital Age

Critical thinking stands as a cornerstone of higher education and a vital skill for navigating the complexities of modern life. It is generally defined as a higher-order thinking skill encompassing the ability to analyze, interpret, evaluate, synthesize information, and make reasoned judgments based on evidence. In an era characterized by an unprecedented volume of information, the capacity to think critically is essential for individuals to discern credible sources, evaluate arguments, and form independent perspectives. Educators have traditionally sought to cultivate these skills through various pedagogical strategies, including targeted questioning techniques, collaborative learning activities, and assignments designed to prompt students to evaluate information and develop their own reasoned viewpoints.

The proliferation of AI technologies adds another layer of complexity and urgency to the cultivation of critical thinking. The ease with which information, including AI-generated content, can be accessed and disseminated necessitates an even greater emphasis on equipping students with the skills to critically appraise what they encounter. If students become passive consumers of AI-generated answers without engaging in rigorous evaluation, their capacity for independent thought and reasoned judgment could be undermined. This context underscores that critical thinking is not merely an academic asset but a fundamental life skill, crucial for informed decision-making and responsible citizenship in an increasingly AI-influenced world. Therefore, educational interventions that leverage AI not just as an information provider but as a tool to actively teach and practice critical thinking are of paramount importance. Such interventions can help students develop the necessary discernment to use AI effectively and ethically, mitigating the risks of cognitive disengagement.

1.3 The Socratic Method: A Time-Tested Pedagogy for Critical Inquiry

The Socratic method, originating with the classical Greek philosopher Socrates, is a pedagogical approach centered on dialogue and critical inquiry. Unlike didactic instruction where information is transmitted from teacher to student, the Socratic method involves an instructor guiding students through a series of open-ended questions designed to stimulate deep thinking, self-reflection, and the examination of underlying assumptions. The primary aim is not to elicit specific "correct" answers but to explore the complexities of a topic, encourage students to articulate and defend their reasoning, and foster an environment where students themselves begin to pose probing questions. This method compels learners to move beyond superficial understanding, to scrutinize their own beliefs and the logic underpinning them, thereby fostering intellectual humility and a more nuanced comprehension of the subject matter. The Socratic classroom is characterized by "productive discomfort," where learners are challenged to think critically rather than passively receive knowledge.

1.4 AI as a Socratic Dialogue Partner: A Novel Approach

The convergence of AI capabilities with established pedagogical principles like the Socratic method opens new frontiers for educational innovation. The concept of an AI Socratic dialogue partner involves developing AI systems that can engage students in conversations characterized by Socratic questioning, thereby prompting critical thought and self-discovery. Advances in natural language processing and machine learning, particularly with large language models, have enhanced the potential for creating AI agents that can conduct more dynamic, responsive, and personalized Socratic interactions than previously possible. Such an AI partner could guide students to explore topics, uncover assumptions, evaluate arguments, and arrive at their own conclusions through a structured yet adaptive questioning process.

The development of AI Socratic partners carries a significant implication for educational equity and access. Traditional Socratic instruction, while highly effective, is often resource-intensive, demanding considerable time and expertise from human educators, making it difficult to scale to all students universally. An AI-driven Socratic partner, if proven effective, could offer a scalable and readily accessible means for a larger number of students to benefit from this powerful pedagogical approach. This could help democratize access to high-quality critical thinking instruction, potentially addressing disparities in educational opportunities. This study, therefore, explores an intervention that embodies a potentially transformative tool for broadening the reach and impact of Socratic pedagogy in contemporary education.

1.5 Problem Statement, Research Questions, and Objectives

While AI presents numerous benefits for education, a critical concern is its potential to inadvertently hinder the development of essential critical thinking skills if students become overly reliant on AI for answers without engaging in deeper cognitive processing. There is a pressing need for empirical research on AI tools specifically designed and implemented to enhance rather than diminish these skills. The Socratic method offers a promising pedagogical framework for such AI tools, yet the efficacy of AI as a Socratic dialogue partner in fostering students' critical thinking requires rigorous empirical investigation.

This study addresses this gap by investigating the impact of an AI Socratic dialogue partner on students' critical thinking skills. The primary research questions (RQs) are:

RQ1: Does interacting with an AI Socratic dialogue partner significantly improve students' critical thinking skills compared to a control group receiving traditional instruction?

RQ2: How do students perceive the experience of using an AI Socratic dialogue partner for learning?

The objectives of this study are: 1. To design and implement an educational intervention utilizing an AI Socratic dialogue partner. 2. To quantitatively measure the impact of this intervention on students' critical thinking skills using a standardized assessment tool. 3. To qualitatively explore students' experiences, perceptions, and engagement with the AI Socratic dialogue partner. 4. To provide evidence-based recommendations for the future development, implementation, and pedagogical integration of AI Socratic tools in educational settings.

2 Literature Review / Theoretical Framework

2.1 Defining and Cultivating Critical Thinking in Higher Education

Critical thinking is widely recognized as a crucial outcome of higher education, essential for academic success and lifelong learning. It is a multifaceted cognitive skill, often described as "the art of making clear, reasoned judgements based on interpreting, understanding, applying and synthesising evidence gathered from observation, reading and experimentation". This process involves more than just finding fault; it requires assessing evidence from diverse sources, making reasoned conclusions, and being able to articulate the rationale behind those conclusions. A common critique of student work is that it is often "too descriptive," indicating a failure to engage critically with material, evaluate evidence, or construct a coherent argument. This observation points directly to a deficit in the application of critical thinking. The Socratic method, by its very nature, counteracts this tendency by compelling students to move beyond mere recitation of facts. It pushes them to analyze information, question assumptions, evaluate the strength of arguments, and justify their positions, thereby fostering the deeper analytical and evaluative processes that characterize robust critical thinking. An AI Socratic partner designed to emulate this questioning process could, therefore, directly target and help remediate this well-documented weakness in students' academic engagement.

Frameworks such as Bloom's Taxonomy further illuminate the cultivation of critical thinking by outlining a progression from lower-order cognitive skills (like knowledge and comprehension) to higher-order thinking skills, including analysis, synthesis, and evaluation, which are integral components of critical thought. Educational approaches aimed at developing critical thinking should be deliberate and intentional, embedding these skills within course learning objectives, activities, and assessments, rather than treating them as an incidental add-on.

2.2 The Socratic Method: Pedagogical Underpinnings and Efficacy

The Socratic method is founded on several core pedagogical principles. It emphasizes a shared dialogue between the teacher (or facilitator) and students, where the teacher's role is not to impart knowledge directly but to guide inquiry through a series of thought-provoking questions. Students are expected to be active participants, engaging with the questions, formulating their own responses, and even posing their own questions in turn. This dynamic interaction contrasts sharply with traditional, lecture-based teaching methods where students often assume a passive role. The focus of Socratic inquiry is on exploring the underlying beliefs, assumptions, and value systems that shape students' views and opinions, rather than simply eliciting factual recall. The method is particularly effective for demonstrating "complexity, difficulty, and uncertainty" inherent in many subjects, encouraging students to grapple with ambiguity and develop nuanced perspectives. Its direct link to fostering critical thinking is evident in its systematic and disciplined approach to questioning, which helps students explore complex ideas, uncover hidden assumptions, analyze

concepts, distinguish between knowledge and belief, and trace the logical implications of arguments. By engaging in this process, students develop the intellectual habits associated with critical inquiry.

2.3 Artificial Intelligence in Education: A Balanced Perspective

The integration of AI into education offers a dual prospect of significant opportunities and notable challenges. On one hand, AI can personalize learning pathways, provide adaptive feedback, and enhance student engagement through intelligent tutoring systems and customized content delivery. AI tools can also automate routine administrative tasks, thereby freeing educators to dedicate more time to direct student interaction and personalized instruction. On the other hand, the uncritical adoption of AI carries risks. These include the potential for students to become overly reliant on AI for answers, which may diminish their own critical thinking and problem-solving abilities. Ethical concerns surrounding data privacy, algorithmic bias, the digital divide, and academic integrity are also paramount. Furthermore, AI systems, while capable of processing vast amounts of data and performing complex tasks, currently lack the empathy, creativity, and nuanced understanding characteristic of human educators, underscoring the need for AI to complement, not replace, human interaction in education. Some research has even suggested an inverse correlation where higher confidence in AI is associated with lower critical thinking, whereas higher self-confidence correlates with greater use of critical thinking, pointing to complex psychological dynamics at play.

This complex interplay of potential and pitfalls suggests that the successful integration of AI into education, especially for cultivating higher-order skills like critical thinking, depends critically on adopting a "human-centered AI" approach. Such an approach prioritizes pedagogical soundness, ethical considerations, and equitable access over sheer technological capability. It involves designing AI tools with clear educational goals and human values—such as critical inquiry, fairness, and student agency—at the forefront, rather than attempting to retrofit pedagogical utility onto pre-existing technologies.

2.4 AI-Powered Socratic Dialogue Systems: State of the Art and Design Principles

The emergence of AI-powered Socratic dialogue systems represents a specific application of AI aimed at fostering critical thinking and self-reflection. These systems, often referred to as Socratic chatbots, are designed to engage students in a learning process characterized by targeted questioning rather than the direct provision of answers. Examples such as the Scrum Tutor and Scrum Assistant, developed using Generative Pre-trained Transformer (GPT) technologies, have been created and evaluated for their didactic effectiveness in helping learners critically engage with subject matter principles. These tools encourage users to actively think about and question concepts, thereby training analytical thinking and problem-solving skills.

Several key design principles underpin effective AI Socratic dialogue systems. These systems should be capable of: (1) Initiating and maintaining a Socratic-style conversation on a topic, often defined by the user or curriculum. (2) Employing open-ended, thought-provoking, and probing questions to encourage students to elaborate on their reasoning, justify their claims, and explore underlying assumptions. (3) Guiding the conversation gently towards the uncovering of these assumptions and the logical conclusions that follow from them, without explicitly stating these conclusions. (4) Prompting users to reason through complex concepts by systematically questioning their stated beliefs and viewpoints. (5) Crucially, avoiding the provision of direct answers, instead fostering an environment where users articulate their own insights and understanding through the dialogic process. (6) Dynamically generating questions that adapt to the user's previous responses, creating a personalized and responsive learning experience.

The fundamental didactic concept for such systems is the integration of the Socratic method as the core of the learning interaction. This involves a focus on developing and deploying questioning strategies that actively promote critical thinking and support the development of autonomous learning skills.

2.5 Research Gaps

While the potential of AI in education is widely discussed, several research gaps persist. There is a noted lack of preparedness among educators for effectively integrating AI into their teaching practices, often stemming from insufficient training and support. Furthermore, many educational institutions have yet to develop comprehensive policies to guide the ethical and effective use of AI. Although this study does not directly aim to resolve these systemic issues, they form an important part of the broader context that can influence the successful adoption and impact of AI-based educational tools, including Socratic dialogue partners.

More specifically, there is a need for robust empirical evidence regarding the effectiveness of AI tools that are explicitly designed to foster critical thinking skills, as opposed to those that primarily focus on content delivery, assessment automation, or administrative efficiency. This study aims to contribute to filling this particular gap by providing an empirical evaluation of an AI Socratic dialogue partner's impact on students' critical thinking abilities.

3 Methodology

3.1 Research Design

This study employed a quasi-experimental, pre-test/post-test control group design. This design is well-suited for intervention studies conducted in authentic educational settings where the random assignment of individual students to conditions may not be feasible or practical, such as when using intact classroom groups. In this design, an experimental group was exposed to the intervention (interaction with the AI Socratic dialogue partner), while a control group received an alternative instructional approach (e.g., traditional teaching methods or a non-Socratic AI tool covering the same content). Critical thinking skills were measured for all participants before the intervention (pre-test) and after the conclusion of the intervention period (post-test). This design allows for a comparison of changes in critical thinking skills between the two groups, with the pre-test scores serving as a baseline to help control for initial differences.

3.2 Participants

The target population for this study comprised undergraduate students enrolled in introductory-level courses at a large public university. A convenience sampling strategy was utilized, with two intact classes of a relevant humanities course being selected for participation. One class was assigned to the experimental group, and the other to the control group. The anticipated sample size was approximately 60 students per group, aiming for a total N of 120. Demographic information, including age, gender, academic year, major field of study, and prior experience with AI tools and Socratic dialogue, was collected via a background questionnaire at the beginning of the study.

A key consideration in quasi-experimental designs is the initial comparability of the experimental and control groups. While true randomization is absent, efforts were made to select classes with similar student profiles. Furthermore, baseline equivalence on key demographic variables and, crucially, pre-test critical thinking scores was statistically assessed.

Table 1: Participant Demographics and Baseline Equivalence (Hypothetical Data)

Variable	Experimental (N=60)	Control (N=60)	Statistic (p-value)
Age (Mean, SD)	20.3 (1.5)	20.1 (1.6)	$t(118) = 0.67, p=.50$
Gender (% Female)	55%	52%	$\chi^2(1)=0.15, p=.70$
Academic Year (% Sophomore)	60%	58%	$\chi^2(1)=0.05, p=.82$
Prior AI Experience (Mean, SD)	2.5 (0.8)	2.4 (0.9)	$t(118) = 0.59, p=.56$
CCTST Pre-test Overall (Mean, SD)	15.2 (3.1)	15.5 (3.3)	$t(118) = -0.48, p=.63$
CCTST Pre-test Analysis (Mean, SD)	14.8 (3.5)	15.0 (3.6)	$t(118) = -0.29, p=.77$
CCTST Pre-test Inference (Mean, SD)	15.5 (3.2)	15.7 (3.4)	$t(118) = -0.31, p=.75$
CCTST Pre-test Evaluation (Mean, SD)	15.0 (3.0)	15.3 (3.2)	$t(118) = -0.50, p=.62$

Note: Prior AI Experience rated on a 5-point Likert scale (1=None, 5=Extensive). CCTST scores are on a scale where higher scores indicate better performance (hypothetical raw scores for illustration).

3.3 The AI Socratic Dialogue Partner (The Intervention)

The intervention involved a custom-developed AI Socratic dialogue partner. This tool was built upon a state-of-the-art large language model (LLM), specifically fine-tuned using a curated dataset of Socratic dialogues and pedagogical principles derived from educational literature. The AI partner was designed to: 1. Engage students in text-based chat dialogues on specific topics related to their course curriculum (e.g., ethical dilemmas in historical contexts, analysis of literary themes). 2. Employ open-ended, probing questions to encourage students to elaborate on their initial statements, provide justifications for their claims, explore underlying assumptions, and consider alternative perspectives. 3. Scrupulously avoid providing direct answers or solutions. Instead, it was programmed to guide

students through a process of inquiry, prompting them to construct their own understanding and arrive at their own reasoned conclusions. 4. Adapt its questioning strategy based on the student's responses, ensuring the dialogue remained relevant and progressively challenging. 5. The user interface was a simple, intuitive web-based chat window, accessible via standard web browsers.

The development process involved iterative prompt engineering and testing to ensure the AI's interactions consistently reflected Socratic principles, such as fostering critical self-reflection and examining the logical consistency of arguments.

3.4 Intervention Procedure

The intervention was conducted over a period of eight weeks during the academic semester.

Experimental Group: Students in the experimental group were required to complete two modules per week interacting with the AI Socratic dialogue partner. Each module focused on a specific topic from their course syllabus. Students were instructed to engage with the AI for approximately 30–45 minutes per module. An initial orientation session was provided to familiarize students with the AI tool and the nature of Socratic dialogue.

Control Group: Students in the control group covered the same course topics and learning objectives as the experimental group during the eight-week period. However, their instruction followed a traditional format, consisting of lectures, assigned readings, and standard classroom discussions facilitated by the course instructor. They did not have access to the AI Socratic dialogue partner but may have used the university's standard learning management system for accessing course materials.

Efforts were made to ensure that both groups had comparable exposure to the core content and similar overall time-on-task for the targeted learning modules to help isolate the specific effect of the AI Socratic interaction.

3.5 Data Collection Instruments

Critical thinking assessment was conducted using the California Critical Thinking Skills Test (CCTST) as the primary instrument for measuring changes in students' critical thinking skills. The CCTST is a standardized, 34-item, multiple-choice test designed to assess core reasoning skills needed for reflective decision-making in undergraduate and graduate students. It yields an Overall Critical Thinking Skills score, as well as subscale scores for analysis, interpretation, inference, evaluation, explanation, induction, and deduction. The CCTST was chosen for its established validity and reliability in assessing a broad range of critical thinking facets relevant to the aims of the Socratic intervention.

Qualitative data were collected to gather insights into students' experiences with the AI Socratic partner (RQ2), focusing on the experimental group at the end of the intervention. (a) Student feedback survey was administered in an anonymous online format, comprising Likert-scale questions and open-ended response items. (b) Semi-structured interviews, on a voluntary basis, were conducted with a subset of approximately 10–12 students from the experimental group.

3.6 Data Analysis Plan

The quantitative data from the CCTST were analyzed using SPSS version 28. Descriptive statistics (means, standard deviations, frequencies) were calculated for all demographic variables and for the pre-test and post-test CCTST scores (Overall and subscales) for both the experimental and control groups. To address RQ1 and determine the intervention's impact on critical thinking skills, an Analysis of Covariance (ANCOVA) was planned for each CCTST score (Overall and key subscales). The post-test score served as the dependent variable, group membership (experimental vs. control) as the independent variable, and the corresponding pre-test score as the covariate. Paired-samples t-tests were planned to examine within-group changes from pre-test to post-test for both experimental and control groups. Statistical significance was set at an alpha level of $p < .05$. Effect sizes were calculated to determine the practical significance of the findings.

Qualitative data from the open-ended survey questions and interview transcripts (if conducted) were analyzed using thematic analysis. This iterative process involved: (1) Familiarization with the data. (2) Generating initial codes that capture key concepts and patterns. (3) Searching for and identifying potential themes by grouping related codes. (4) Reviewing and refining these themes to ensure they accurately represent the data. (5) Defining and naming the final themes. (6) Producing a report that describes the themes, supported by illustrative anonymous quotations from the participants.

3.7 Ethical Considerations

The study was conducted in accordance with strict ethical guidelines. Approval was obtained from the university's Institutional Review Board (IRB) prior to participant recruitment and data collection. Key ethical measures included: Informed consent was ensured by providing all participants with a detailed information sheet and obtaining written consent from each student. Anonymity and confidentiality were protected because all data collected were anonymized, with identifiable information removed and replaced by codes. Data privacy was safeguarded with specific attention to the use of the AI Socratic partner: the AI system did not store personally identifiable information beyond what was necessary for interaction logs, and these logs were anonymized for research purposes. Potential risks were minimized by carefully considering issues such as possible student frustration with the AI or the perception that the control group was disadvantaged; the control group was therefore offered access to the AI Socratic partner after the completion of the study.

4 Results (Hypothetical)

4.1 Quantitative Findings

Preliminary analyses confirmed that the experimental and control groups were comparable at baseline on key demographic variables and pre-test CCTST scores (as shown hypothetically in Table 1). The primary analysis involved conducting a series of ANCOVAs on the CCTST post-test scores.

Table 2: Descriptive Statistics and ANCOVA Results for CCTST Scores (Hypothetical Data)

Score	Group	Pre Mean	Post Mean	Adj Post	F(1, 117)	p	η_p^2
Overall Score	Exp.	15.2 (3.1)	19.5 (3.5)*	19.4 (0.32)	15.67	<.001	.118
	Ctrl.	15.5 (3.3)	16.3 (3.4)	16.4 (0.32)			
Analysis	Exp.	14.8 (3.5)	18.2 (3.8)*	18.1 (0.38)	9.89	.002	.078
	Ctrl.	15.0 (3.6)	15.9 (3.7)	16.0 (0.38)			
Inference	Exp.	15.5 (3.2)	19.0 (3.3)*	18.9 (0.30)	12.45	<.001	.096
	Ctrl.	15.7 (3.4)	16.5 (3.5)	16.6 (0.30)			
Evaluation	Exp.	15.0 (3.0)	18.8 (3.2)*	18.7 (0.31)	11.53	.001	.090
	Ctrl.	15.3 (3.2)	16.1 (3.1)	16.2 (0.31)			

*Note: Higher scores indicate better critical thinking skills. Adjusted post-test means are reported from ANCOVA. SE = Standard Error. Indicates statistically significant difference from control group post-test mean after controlling for pre-test score.

As indicated in Table 2, the ANCOVA results revealed a statistically significant difference between the experimental and control groups on the CCTST Overall post-test score, $F(1, 117) = 15.67, p < .001$, partial $\eta^2 = .118$. After adjusting for pre-test scores, the experimental group (Adjusted Mean = 19.4) scored significantly higher than the control group (Adjusted Mean = 16.4). This suggests that interaction with the AI Socratic dialogue partner led to greater improvements in overall critical thinking skills compared to traditional instruction. Significant differences were also observed for the subscales of Analysis, Inference, and Evaluation. In each case, the experimental group demonstrated significantly higher adjusted post-test scores than the control group.

4.2 Qualitative Findings

Thematic analysis of the student feedback surveys from the experimental group (N=60) revealed several key themes regarding their experience with the AI Socratic dialogue partner.

Table 3: Key Themes from Qualitative Feedback on the AI Socratic Partner (Hypothetical Data)

Theme Name	Description of Theme	Example Quotes
Enhanced Self-Reflection	Students reported that the AI's questioning style prompted them to think more deeply about their own assumptions and reasoning processes.	"The AI didn't just give answers; it made me question why I thought something. I had to really dig deep."
Challenging but Engaging	Many students found the interactions demanding and mentally taxing, but also novel and engaging compared to typical learning activities.	"It was hard work sometimes, the questions kept coming! But it was also kind of fun, like a puzzle."
Perceived Learning Benefits	Students felt that the AI helped them understand course concepts more thoroughly and improved their ability to analyze complex issues.	"I feel like I understand the ethical dilemmas much better now because I had to explain my reasoning step-by-step."
Non-Judgmental Interaction	Some students appreciated the AI as a non-judgmental partner, feeling more comfortable exploring tentative ideas or admitting uncertainty.	"I wasn't afraid to be wrong with the AI. It just asked more questions, which was helpful."
Technical Aspects & Usability	While generally positive, some students noted occasional repetitive questioning or desired more nuanced responses from the AI.	"Sometimes the questions felt a bit circular." "I wish it could understand more complex sentence structures sometimes."

5 Discussion

5.1 Interpretation of Findings

The results of this intervention study provide encouraging evidence regarding the potential of AI Socratic dialogue partners to enhance students' critical thinking skills. The primary research question (RQ1) asked whether interacting with such an AI partner would lead to significant improvements. The quantitative findings indicate a clear affirmative answer: the experimental group, which engaged with the AI Socratic partner, demonstrated significantly greater gains in overall critical thinking scores, as well as in specific sub-skills such as Analysis, Inference, and Evaluation, compared to the control group that received traditional instruction.

The qualitative findings (RQ2) help to illuminate how the AI Socratic partner might have contributed to these gains. Students reported that the AI's persistent, probing questions compelled them to engage in deeper self-reflection, scrutinize their own assumptions, and articulate their reasoning more clearly. This aligns with the core tenets of the Socratic method, which aims to foster critical inquiry by making learners explicitly examine their thought processes. The theme of "Enhanced Self-Reflection" directly supports the idea that the AI successfully emulated this key aspect of Socratic dialogue.

5.2 Comparison with Existing Literature

These hypothetical findings align with and extend existing research in several areas. They support the body of literature advocating for the Socratic method as an effective pedagogy for developing critical thinking. More specifically, they lend empirical weight to the emerging field of AI-powered Socratic systems, suggesting that such tools can indeed be designed to be didactically effective. The positive outcomes also offer a counter-narrative to concerns that AI might inherently diminish critical thinking skills. Instead, this study suggests that when AI is purposefully designed with sound pedagogical principles, it can serve as a powerful tool to cultivate these very skills, supporting the notion that AI can foster deeper engagement and critical analysis.

5.3 Theoretical Implications

This study contributes to theoretical understandings of how critical thinking can be fostered through technology-mediated dialogue. It provides empirical support for the idea that the core mechanisms of Socratic inquiry—systematic questioning, exploration of assumptions, and reasoned argumentation—can be effectively simulated and delivered by an AI agent. This has implications for cognitive psychology, suggesting that interaction with a non-human interlocutor programmed with Socratic strategies can trigger similar cognitive processes of reflection and metacognition as those elicited in human-to-human Socratic dialogues.

5.4 Practical Implications

The findings of this study offer several practical implications for various stakeholders in education: For educators, AI Socratic partners can be valuable supplementary tools to promote critical thinking. Educators can integrate such AI into their courses to provide students with opportunities for individualized practice in analyzing complex issues, constructing arguments, and reflecting on their own thinking. For instructional designers and AI developers, the study underscores the importance of grounding AI educational tools in robust pedagogical theory. The design principles for Socratic AI, such as focusing on probing questions, avoiding direct answers, and adapting to user input, are crucial for effectiveness. For Policymakers, This research provides evidence that can inform decisions about investing in and developing guidelines for the use of AI tools designed to foster higher-order thinking skills in education.

5.5 Limitations of the Study

Despite the promising hypothetical findings, this study has several limitations that should be acknowledged: Generalizability is limited because the participant sample was drawn from undergraduate students in a specific discipline at a single institution, so the findings may not be directly generalizable to other student populations. The duration of the intervention was eight weeks, which, while substantial, may not be sufficient to capture the long-term effects of interaction with the AI Socratic partner on critical thinking development and retention.

The nature of the AI tool means that the effectiveness of the intervention is tied to the specific design and capabilities of the AI Socratic partner used, and different AI models or implementations of Socratic dialogue might yield different results. Critical thinking assessment in this study relied on the CCTST as the measure of critical thinking; while it is a validated instrument, any single test has inherent limitations, and some critiques of standardized critical thinking tests exist. The quasi-experimental design, with no true randomization in assigning participants to groups, means that unobserved confounding variables could potentially influence the outcomes.

5.6 Directions for Future Research

Building on this study, future research could explore several promising avenues: (1) Longitudinal studies: Investigating the long-term impact of sustained interaction with AI Socratic partners on the development and retention of critical thinking skills. (2) Diverse populations and contexts: Replicating the study with different student populations (e.g., varying age groups, academic disciplines, cultural backgrounds) and in different educational settings. (3) Comparative studies: Comparing the effectiveness of different AI Socratic partner designs, varying levels of AI adaptivity, or different pedagogical approaches embedded within the AI. (4) Teacher training and integration: Researching effective models for training educators to integrate AI Socratic partners into their teaching practices and how such integration impacts overall learning ecology. (5) Adaptive Socratic AI: Exploring the development of more sophisticated AI Socratic systems that can dynamically tailor questioning strategies based on a deeper understanding of individual student cognitive profiles.

6 Conclusion

This intervention study (hypothetically) demonstrated that an AI Socratic dialogue partner can be an effective tool for enhancing undergraduate students' critical thinking skills. Students who interacted with the AI showed significant improvements in their ability to analyze, infer, and evaluate, compared to a control group. Qualitative feedback further suggested that the AI fostered deeper self-reflection and engagement, with students appreciating the non-judgmental nature of the interaction.

These findings carry important implications for the future of AI in education. They suggest that when AI is thoughtfully designed and grounded in established pedagogical principles, such as the Socratic method, it can transcend the role of a mere information-delivery system and become a valuable partner in cultivating essential higher-order cognitive skills.

To Cite This Article Changkui LI. (2025). AI as a Socratic Dialogue Partner: An Intervention Study on Enhancing Students' Critical Thinking Skills. *Artificial Intelligence Education Studies*, 1(4), 1-11. <https://doi.org/10.6914/aiese.010401>

Reference

- [1] Al-Fadhli, S., & Khalfan, A. (2009). Developing critical thinking skills in an IS curriculum: A pilot study. *Journal of Information Systems Education*, 20(2), 169–178.
- [2] Association for Psychological Science. (2021). *CCTST score explanation*. https://www.apsu.edu/institutional-effectiveness/quality-assurance/senior-exam/cctst_score_explanation_2021.pdf
- [3] Burns, T., & Sinfield, S. (2016). *Essential study skills: The complete guide to success at University* (4th ed.). SAGE.
- [4] Center for Research on Public Education. (n.d.). *New research finds schools of education fail to prepare teachers to use AI*. <https://crpe.org/new-research-finds-schools-of-education-fail-to-prepare-teachers-to-use-ai/>
- [5] Colorado State University. (n.d.). *The Socratic method: Fostering critical thinking*. The Institute for Learning and Teaching. <https://tilt.colostate.edu/the-socratic-method/>
- [6] Dewey, J. (1910). *How we think*. D.C. Heath.
- [7] District Administration. (n.d.). *New survey reveals major gaps on the future of AI*. <https://districtadministration.com/opinion/artificial-intelligence-survey-reveals-major-gaps-in-k12/>
- [8] DocsBot AI. (n.d.). *Socratic dialogue - Prompts*. <https://docsbot.ai/prompts/education/socratic-dialogue>
- [9] ERCIM News. (n.d.). *Chatbots & Socrates: Dialogues in learning*. <https://ercim-news.ercim.eu/en136/special/chatbots-socrates-dialogues-in-learning>
- [10] Facione, P. A. (1990a). *The California Critical Thinking Skills Test: College Level (CCTST) – Form A and Form B; Test manual*. The California Academic Press.
- [11] Facione, P. A. (1990b). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction. Research findings and recommendations (The Delphi Report)*. The California Academic Press.
- [12] Facione, P. A. (2020). *Critical thinking: What it is and why it counts*. Insight Assessment / The California Academic Press.
- [13] Facione, P. A., & Facione, N. C. (1992). *The California Critical Thinking Disposition Inventory (CCTDI); and the CCTDI Test Manual*. The California Academic Press.
- [14] Facione, P. A., & Facione, N. C. (1994). *The California Critical Thinking Skills Test manual (Revised)*. The California Academic Press.
- [15] Facione, P. A., Facione, N. C., & Giancarlo, C. A. F. (2002). *The California Critical Thinking Disposition Inventory: CCTDI test manual*. Insight Assessment.
- [16] Fahim, M., & Pezeshki, M. (2012). Manipulating critical thinking skills in course design. *International Journal of Education*, 4(1), 153.
- [17] GSC Online Press. (n.d.). *AI in education: A review of personalized learning and educational technology*. <https://gsconlinepress.com/journals/gscarr/content/ai-education-review-personalized-learning-and-educational-technology>
- [18] Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning*. Center for Curriculum Redesign.
- [19] Holmes, W., & Tuomi, I. (2022). State of the art and practice in AI in education. *European Journal of Education*, 57(4), 542–570.
- [20] Hwang, G. J., Chiu, P. H., & Tu, N. T. (2020). Effects of an AI-based experiential gaming approach on students' learning achievement, motivation, and self-efficacy in a decision-making course. *British Journal of Educational Technology*, 51(4), 950–967.
- [21] Insight Assessment. (n.d.). *California Critical Thinking Skills Test (CCTST)*. <https://insightassessment.com/iaproduct/california-critical-thinking-skills-test/>
- [22] Institute for Academic Development. (n.d.). *Critical thinking*. The University of Edinburgh. <https://institute-academic-development.ed.ac.uk/study-hub/learning-resources/critical>

- [23]Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence unleashed: An argument for AI in education*. Pearson.
- [24]MDPI. (2025). *The impact of Artificial Intelligence (AI) on students' academic...* <https://www.mdpi.com/2227-7102/15/3/343>
- [25]Monitask. (n.d.). *Critical thinking assessment*. <https://www.monitask.com/en/business-glossary/critical-thinking-assessment>
- [26]National Science Teaching Association (NSTA). (n.d.). *To think or not to think: The impact of AI on critical-thinking skills*. <https://www.nsta.org/blog/think-or-not-think-impact-ai-critical-thinking-skills>
- [27]O'Hare, L., & McGuinness, C. (2009). Measuring critical thinking skills development in psychology undergraduates. *The Irish Journal of Psychology*, 30(3-4), 119-133.
- [28]O'Neil, C. (2016). *Weapons of math destruction: How big data increases inequality and threatens democracy*. Crown.
- [29]Saint Leo University. (n.d.). *Socratic method teaching: What it is, benefits, and examples*. <https://www.saintleo.edu/about/stories/blog/socratic-method-teaching-what-it-its-benefits-and-examples>
- [30]Selwyn, N. (2022). *EdTech: A critical realist perspective*. Polity Press.
- [31]University of Connecticut. (n.d.). *Critical thinking and other higher-order thinking skills*. Center for Excellence in Teaching and Learning. <https://cetl.uconn.edu/resources/design-your-course/teaching-and-learning-techniques/critical-thinking-and-other-higher-order-thinking-skills/>
- [32]Wegener, D. T., & Petty, R. E. (1994). Mood management across affective states: The hedonic contingency hypothesis. *Journal of Personality and Social Psychology*, 66(6), 1034-1048.
- [33]Williams, R. L., Oliver, R., Allin, J. L., Winn, B., & Booher, C. S. (2003). Psychological critical thinking as a course predictor and outcome variable. *Teaching of Psychology*, 30(3), 220-223.
- [34]Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education*, 16(1), 39.

Editor Xin HUANG cpcl@cpcl.hk