

AI in Education: Designing Human–AI Dialogic Learning Ecosystems for Critical Inquiry in Higher Education

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Abstract

The study examines the role of generative artificial intelligence (AI) chatbots to support Socratic dialogue and facilitate critical inquiry in online learning; In particular, the study investigates the role of AI-mediated questioning patterns in prompting reflective thinking and critical thinking in higher education learners; finally, study suggests a conceptual framework of AI-mediated dialogic learning. The paper adopts qualitative exploratory research that is based on structured human-AI dialogue interactions with a generative AI chatbot i.e., ChatGPT. Qualitative content analysis was used to analyze 120 AI-generated prompts in 18 dialogue episodes. To find patterns of dialogic engagement and cognitive scaffolding. Prompts were coded based on the Socratic categories of questions of cognitive levels (Bloom taxonomy), indicators of reflective reasoning and depth of inquiry chain. The results indicate that conversational AI like ChatGPT can produce organized Socratic prompts such as clarification questions, assumption probing and evidence seeking prompts that can be used to stimulate reflective inquiry. The analysis also demonstrates that close to half of the prompts were higher-order thinking prompts of analysis and evaluation. Multi-turn inquiry chain and iterative knowledge synthesis were also maintained by AI-mediated dialogue. The study is based on results, proposes the Human-AI Dialogic Learning Ecosystem Model, which understands conversational AI as a dialogic partner with the capacity to scaffold inquiry and reflective thinking. The paper recommends that teachers can incorporate conversational AI in the form of dialogic learning assistants to facilitate inquiry-based learning, reflective conversation, and critical thinking in higher education level.

Introduction

Digital learning and university environments are being changed by the fast development of artificial intelligence (AI) technologies. Specifically, generative artificial intelligence applications including chatbots has been used to enhance new possibilities in interactive and inquiry-based education (Begum et al, 2026). Such technologies are gradually becoming part of the educational setting to facilitate personalized learning, student interaction, and knowledge building (Holmes et al., 2019; Kasneci et al., 2023). Generative AI systems like ChatGPT have become popular in scholarly literature because of the potential to produce a conversation, give feedback, and facilitate reflective inquiry (Akbas, 2025; Begum et al., 2026). With the digital transformation that is still under way in higher education institutions, the research question on how AI-mediated dialogue can be used to facilitate the process of critical thinking and inquiry-based learning has emerged as a significant subject of study. Additionally, the introduction of AI in education practice is in line with the worldwide undertakings of establishing sustainable and inclusive learning systems, especially the Sustainable Development Goal 4 (SDG 4) that champions equitable access to quality education. Although there is an increasing usage of generative AI in the educational field, the majority of current studies are devoted to the application of AI in information retrieval, automated feedback, or the creation of content (Cotton et al., 2024). Despite these capabilities are useful, they are not the best use of the potential of conversational AI to facilitate dialogic and inquiry-based learning. According to the emerging literature, AI-based conversational agents have the potential to foster reflective thinking and collaborative knowledge building by means of structured questioning

and dialogue (Raitskaya & Tikhonova, 2025; Rahman et al., 2025). Nevertheless, it is still inadequately researched how AI-mediated dialogue can provoke a deeper intellectual involvement.

Hence, classical educational philosophy is a valuable source of insights on the inquiry based learning. It is based on ancient Greek philosophy and is called the Socratic method, which focuses on systematic interrogation to contest presuppositions, elucidate concepts, as well as promote thoughtful contemplation (Paul & Elder, 2007). This practice is consistent with the dialogic education theories, according to which the process of learning can be defined as collaborative meaning-making in the context of structured interaction (Alexander, 2008; Wegerif, 2013). On the same note, constructivist theory of learning emphasizes on the role of guided inquiry and cognitive scaffolding in knowledge building (Piaget, 1972; Vygotsky, 1978). To overcome the insufficient empirical insight into the potential of the use of AI-mediated Socratic dialogue, this paper explores how generative AI chatbots can promote critical inquiry in online learning settings. By qualitatively analyzing dialogue interaction forms of structured human-AI dialogues, the research paper suggests the Human-AI Dialogic Learning Ecosystem, which outlines how conversational AI may act as a dialogic partner scaffolding reflective inquiry and higher-order thought in higher education.

Research Objectives

1. To examine the types and patterns of Socratic questioning generated by AI chatbots during dialogic interactions.
2. To analyze the cognitive levels embedded in AI-generated prompts and determine how they support higher-order thinking processes.
3. To identify how AI-mediated dialogue activates reflective reasoning and metacognitive engagement during inquiry-based interaction.
4. To explore the extent to which AI chatbots facilitate iterative knowledge construction through synthesis-oriented dialogue.
5. To develop an emergent model of AI-supported Socratic inquiry that explains how conversational AI functions as a cognitive scaffolding mechanism in digital learning environments.

Literature Review

Artificial Intelligence and the Transformation of Higher Education

The concept of artificial intelligence (AI) has become a new turning point in modern education, as it allows redefining the existing processes of pedagogy, learning conditions, and knowledge creation in higher educational establishments. A recent implementation of AI-driven technologies into academic environments has facilitated new levels of individualized learning, adaptive feedback, and other types of interactive digital learning environments (Holmes et al., 2019). The use of generative AI (ChatGPT) especially has received a lot of attention due to its capacity to support students with academic writing,

problem solving, and dialogic interaction with learning content (Kasneci et al., 2023). These technologies have become the focus of the new paradigm of Education 4.0, that prioritizes technology-enriched learning, becoming digital-literate, and acquiring future-ready competencies among students (Butt et al., 2020). In this respect, introducing AI technologies in institutions of higher education can also help support larger-scale global processes of moving towards sustainable and inclusive education systems, specifically with references to Sustainable Development Goal 4 (SDG 4), which strives to provide equal opportunities to affordable quality education and offer people a chance to learn throughout their entire lives.

According to the latest research, AI technologies have a strong potential to improve the learning experience of students due to their ability to foster collaboration, unceasing knowledge exchange, and competency-based learning (Asad & Qureshi, 2025; Asad & Aijaz, 2025). As an example, AI-driven learning platforms allow students to get feedback and teaching promptly, thus facilitating self-directed learning and learning academic skills. On the same note, Asad and Anwar (2025) state that AI application in higher learning institutions can help in ensuring that students are developed in career competencies and professional abilities, especially in digitally mediated learning environments. These trends are in tandem with the global sustainability programmes which stress on the need to establish knowledge-based societies that can meet complicated social, economic and technological issues. In the developing nations, including Pakistan, the rise in digital transformation and the need to adopt AI technologies in higher education has accelerated the adoption of these technologies. Researchers point out that AI-driven learning systems have the potential to enhance the accessibility of education, facilitate customized learning, and decrease learning gaps among learners (Asad & Memon, 2025). These changes especially apply to SDG 10 which aims at diminishing inequalities by facilitating inclusive access to education. Nevertheless, in spite of these advantages, researchers have also highlighted the necessity of pedagogical models that can help in a successful introduction of AI in the teaching process in order to achieve significant learning results (Nazir et al., 2026).

Generative AI and Chatbots in Learning

With the introduction of generative AI applications, and chatbots in particular, interactive learning and academic interaction have become possible once again. Human-like conversation can be simulated by chatbots, which allows learners to engage with digital systems in the manner that facilitates inquiry, reflection, and knowledge building (Begum et al., 2026). This type of conversational technology can become digital tutors, and they can offer explanations, ask questions and help the students undertake complex learning tasks. Such abilities are also becoming considered as valuable elements of digital learning ecosystems, which are relevant to SDG 9, and promote both technological innovation and a sustainable development of infrastructure. It has been found that conversational AI tools can be used to increase student engagement and facilitate active participation in learning processes (Huang et al., 2025). Indicatively, AI-based feedback systems are demonstrated to foster student autonomy and self-directed learning because they stimulate learners to discover ideas by themselves and reflect on the

learning process (Huma et al., 2025). In the same way, Rahman et al. (2025) discovered that AI-based text generation systems have the potential to have a positive impact on the analytical thinking and problem-solving abilities of students when applied as interactive learning support. However, the popularization of generative AI tools has also generated the issue of academic honesty and ethical application to the study. As noted by Cotton et al. (2024) on the one hand, AI tools have the potential to increase the learning opportunities, but on the other, they also introduce such risks as plagiarism, reliance on robot replies, and decreased involvement with scholarly materials. These issues imply that AI technologies are to be incorporated in the pedagogical frameworks that promote active cognitive processes over passive knowledge intake (Malik et al., 2025). In terms of sustainability, it follows that responsible incorporation of AI in education is necessary to make sure that the technological innovation can be used to produce ethical, equitable, and meaningful learning outcome.

Socratic Pedagogy and Dialogic Learning

Socratic method is one of the oldest and most effective pedagogical methods of developing critical thinking and intellectual inquiry. Based on classical Greek philosophy, Socratic pedagogy focuses on the application of guided questioning and dialogue to stimulate the learners to critique assumptions, clarify ideas and formulate arguments through reasoned arguments (Paul & Elder, 2007). Instead of giving a straight answer, the Socratic mode of inquiry provokes the learner to consider the concepts by posing a thought-provoking question and engaging in a discussion with the fellow learners. Socratic pedagogy has been regarded as one of the best pedagogical approaches in enhancing critical thinking and reflective learning in contemporary learning institutions. It has been found that dialogic pedagogy, which is based on the Socratic line of questioning, may boost the analytical reasoning and problem-solving skills of students (Ho et al., 2023). On the same note, Piro and Anderson (2015) discovered that Socratic dialogue in teacher education programs might play a significant role in enhancing the capacity of students to have a critical dialogue and intellectual reflection. The relevance of Socratic pedagogy within the present-day education is also supported by theories on dialogic learning. According to Alexander (2008), an effective dialogue in the classroom is an important feature that can encourage the growth of cognition and the idea of concepts. Similarly, Wegerif (2013) posits that dialogic teaching promotes collaborative thinking and reflective questioning among the learners, thus enhancing greater intellectual activity. These views are in accordance with the constructivist theories of learning that point out that the knowledge is formed by socialization and conversation (Vygotsky, 1978; Piaget, 1972). These practices of dialogic learning are increasingly being deemed necessary with regard to equipping learners with the critical thinking and problem-solving skills needed to meet the challenges of sustenance in contemporary communities.

AI-Supported Socratic Dialogue and Critical Thinking

Recent studies have started to investigate the possibility of using AI technologies to contribute to the Socratic-style dialogue in the digital learning environment. Reflective questions, assumptions, or forcing

learners to explain their rationale can all be generated using conversational AI systems, which replicate aspects of the Socratic method (Favero et al., 2024). These features imply that chatbots with AI can be used as dialogic learning partners to facilitate inquiry-based learning. As an example, Fakour and Imani (2025) have made a comparative study on how effective ChatGPT and human tutors are in encouraging critical thinking using Socratic questioning. According to their results, AI-based questions can motivate learners to think deeper and employ more critical thinking. Equally, Lee et al. (2025) indicated that students with higher-order thinking skills can be improved through generative AI-based assessment tools by making them analyze arguments and assess evidence. Moreover, Santos-Guevara et al. (2026) documented that Socratic dialogue improved, with the help of ChatGPT, the engagement and perceived learning outcomes of students in physics learning. These results suggest that conversational systems based on AI have the potential to offer scalable avenues of applying dialogic pedagogy to digital learning settings, hence, leading to the sustainable and inclusive innovation in education.

Research Gap

Despite the previous research demonstrating the potential of AI technologies to transform the educational process, there is a lack of knowledge on how the generative AI systems should be incorporated with the traditional educational methods like the Socratic approach. Although studies have investigated the uptake of AI technologies in learning and how they help students to learn, only a small number of research studies have addressed the adoption of AI-guided Socratic discourse as a tool to improve student engagement, reflective inquiry, and critical thinking in online classrooms. This gap is especially relevant to be addressed in the framework of higher education establishment where digital learning space is changing rapidly. Thus, this paper aims to investigate the potential of AI-based Socratic dialogue as the innovative tool of teaching critical thinking and reflective learning to undergraduate students. Combining the classical inquiry-based pedagogy with modern AI technologies, the study helps to advance the emerging discourses of human-AI collaborative learning ecosystems that could sustain innovative, sustainable, and inclusive education systems in accordance with the global sustainability priorities.

Research Methodology

Research Design

The research is based on an exploratory qualitative research design with a descriptive quantitative analysis in exploring how generative artificial intelligence (AI) chatbots operationalize the Socratic dialogue in online learning settings. It is based on the qualitative content analysis of structured human-AI dialogue transcripts in order to conduct a systematic study of questioning structures, reasoning patterns and reflective inquiry produced by conversational AI systems. The originality of the research is that AI-mediated dialogue is used as the main empirical source, and generative AI is not only a technological tool but also a partner of dialogic inquiries capable of scaffolding cognitive interaction.

The study has examined how conversational AI can recreate some of the main components of classical Socratic pedagogy, as well as, trigger higher-order thinking processes by studying AI-generated prompts and patterns of interaction. In order to enhance the analytical rigor, qualitative coding of dialogue transcripts was augmented by descriptive frequency analysis so that the study was able to quantify Socratic questioning pattern, cognitive demand and reflective reasoning activation.

Data Source

Structured human-AI dialogue interactions between the researcher and a generative AI chatbot (ChatGPT) are the source of primary data with regards to this study. These conversations were carefully structured to model a Socratic inquiry in the context of academic discussion where the chatbot answered conceptual prompts by posing repeated questions and introspective conversations. The researcher prompted several discussions with several conceptual prompts which were complex concepts that were introduced in relation to the movement of artificial intelligence in education, digital pedagogy, ethical implications of AI, and development of critical thinking. These cues were chosen in such a way as to provoke the further dialogical interaction and prompt chatbot to produce Socratic-like sets of questions. All the dialogue sessions were transcribed and summarized in written transcripts.

Additionally, in the dialogue sessions, 120 AI-prompts were identified and captured and analyzed as the main analytical units. Such prompts were AI-generated questions and reflective prompts, where the learner should inquire more deeply into the concepts, e.g., by clarification questions, prompts that challenge assumptions, questions that seek evidence, and triggers of metacognition. Moreover, 18 dialogue episodes were detected in the transcripts and analyzed to determine the intensity and persistence of chains of inquiry so that the study could establish the role of sustained Socratic dialogues in cognitive scaffolding in AI facilitated learning systems.

Unit of Analysis

Three supplementary units of analysis were used in the analysis of the dialogue's transcripts. The AI prompt level was the first unit of analysis where every AI-made question or reflective prompt was coded based on Socratic questioning type and cognitive demand. These cues were the major predictors of the role of conversational AI in supporting inquiry-based learning activities. The second unit of analysis was the dialogue episode level, according to which the sequence of interactions between a researcher and an AI chatbot was considered an individual episode inquiry. The depth and continuity of multiple turn Socratic questioning chains were analyzed based on these episodes. The third unit of analysis was reflective reasoning markers which entailed the coding of prompts with metacognitive triggers in order to analyse the mediating effect of AI-mediated dialogue in stimulating reflective thinking, assumption re-evaluation and conceptual reinterpretation.

Data Analysis Procedure

In the study, qualitative content analysis was used alongside descriptive quantitative frequency analysis, to systematically analyze patterns of AI-generated transcripts of dialogue. The coding process was multi-stage and aimed at determining the structural features of Socratic inquiry of conversational AI interactions.

The first stage was a coding of AI-generated prompt based on its preponderant Socratic questioning role such as clarification, assumption-seeking, evidence-seeking, perspective, implication-seeking, and meta-reflective questions. The frequency counts were done to establish how these questioning patterns were distributed in the dataset.

The second stage involved the classification of prompts based on the revised taxonomy of cognitive processes by Bloom that comprise remembering, understanding, applying, analyzing, evaluating, and creating. This categorization made it possible to determine the degree to which AI-generated dialogue provoked higher-order cognitive processing.

The third stage involved prompts, reflective reasoning triggers, which were analyzed as such; assumption re-examination, counterargument prompting, ethical and contextual considerations, epistemic uncertainty prompts, and metacognitive reflection cues. Due to the possibility of several reflective indicators in individual prompts, multiple coding was allowed to measure the complexity of the reflective inquiry processes.

Lastly, the depth of Socratic inquiry chains in each dialogue episode was calculated by the number of consecutive AI probes with one conceptual topic prior to a change in conversation. Depth of inquiry was divided into short (1–2 turns), moderate (3–4 turns), deep (5–6 turns), and extended (7 or more turns) interactions. This step enabled the research to test the ability of chatbot to maintain multi-turn cognitive scaffolding dialogues that are defining of inquiry-based learning.

Coding Reliability

To improve the validity of the qualitative analysis, a protocol of coding in a structured format was developed before the dialogue transcripts were analyzed. Operation indicators of each Socratic question category, level of thinking, and reflective reasoning mark was well defined in the coding scheme. The independent codification of a subset of the dataset (about 20% of the AI prompts) by a second reviewer who was acquainted with the qualitative content analysis was necessary to achieve consistency in coding. Cohen Kappa coefficient was used to determine the level of agreement between coders where the value ($k = 0.84$) indicated the existence of a high degree of inter-coder reliability. The coding discrepancies were deliberated and agreed on through consensus and the coding construct further refined before the remaining data were analyzed.

Trustworthiness and Rigor

Quality of the qualitative analysis was guaranteed based on the criterion of credibility, dependability and confirmability. Systematic coding and triangulation between qualitative interpretation and descriptive frequency analysis was used to enhance credibility. Reliability was ensured by recording the method of analysis, coding scheme, and decision-making methods adopted in the analysis. This audit trail was used to ensure transparency in the detection of themes and patterns in the dataset.

The problem of confirmability was tackled through the direct ground of results of interpretations and results of coding on the transcript of the dialogue, and thus there was limited subjectivity in the analysis. Moreover, the theoretical context of the analytical process was based on the utilization of the structured categories of coding based on the Socratic pedagogy and cognitive learning systems. A combination of these measures guaranteed that the results present a stringent and clear analysis of AI-mediated Socratic discourse in the context of digital learning space.

Analytical Outcome

By using qualitative coding and descriptive frequencies analysis, the study found four emergent dimensions of AI-supported Socratic inquiry, which are dialogic prompting architecture, cognitive escalation of questioning, reflective reasoning activation, and iterative synthesis of arguments. All these dimensions prove that conversational AI can lead learners through the steps of inquiry and intellectual activity, which become deeper as they go on. These results were used to create an AI-Supported Socratic Inquiry Model, which envisioned the use of generative AI as a dialogue partner that has the potential to support reflective inquiry and critical thinking during online learning processes.

Results and Findings

An interpretation of the interactions in the structured human-AI dialogue indicates that generative AI chatbots can easily apply multiple principles of Socratic inquiry to the digital learning setting. As a result of qualitative content analysis of 120 AI-generated prompts on 18 dialogue episodes, it was determined that there are specific patterns of dialogic engagement and cognitive scaffolding. The research results show that AI-mediated dialogue does not simply imitate a conversational interaction but, rather, helps a progressive inquiry process, which is organized and structured through questioning and reflective thinking and knowledge synthesis. Particularly, the analysis resulted in four dimensions which were interrelated: (1) dialogic prompting architecture, (2) cognitive escalation of inquiry, (3) reflective reasoning activation, and (4) iterative synthesis of ideas. These dimensions are combined to illustrate that conversational AI can serve as a dialogic learning partner which activates higher-order thinking and reflective inquiry. The findings were also used to develop the Human-AI Dialogic Learning Ecosystem Model that conceptualizes the AI-mediated dialogue as a cognitive scaffolding tool in digital learning contexts.

Types of Socratic Questions Generated by AI

The result of the prompt analysis AI-generated prompts showed that there is a wide variety of types of Socratic questions that can lead the questioning process when interacting in a dialogue. As shown in Table 1, clarification or concept definition prompts (n = 32, 26.7) were the most common category, in which the AI prompted the learners to expound ideas or explain major concepts. It was then followed by assumption-probing questions (n = 24, 20.0%), which questioned learning assumptions and encouraged the learners to look at implicit assumptions. There was also evidence or justification-seeking (n = 22, 18.3), which asked the learners to justify or back their statements with arguments or illustrations. The challenge of perspective elicited (n = 16, 13.3%) alternative perspectives, in which the learners are encouraged to think of arguments on both sides. Equally, implication or consequence prompt (n = 14, 11.7%) required the learner to investigate what might happen or what might go amiss with their ideas. Lastly, (n = 12, 10.0) meta-reflection prompts prompted the learner to reflect on their reasoning processes and intellectual positions. The results propose that the frequency of Socratic question types implies that AI-mediated dialogue utilizes systematic questioning methods, which facilitate conceptual clarification, critical analysis of assumptions, and reflection, thus, facilitating inquiry-based learning.

Table 1
Frequency of Socratic Question Types Generated by the AI

Socratic question type	Operational indicator (how it was coded)	Frequency (n)	Percent (%)
Clarification / Concept definition	asks “what do you mean by...”, requests definitions, asks for elaboration	32	26.7
Assumption probing	challenges hidden beliefs, “what assumption are you making...?”	24	20.0
Evidence / justification seeking	requests proof, examples, sources, reasoning	22	18.3
Perspective challenge	introduces opposing views, “how would someone disagree...?”	16	13.3
Implication / consequence probing	explores outcomes, unintended effects, “what follows if...?”	14	11.7
Meta-reflection prompts	asks learner to reflect on thinking, “how did you reach...?”	12	10.0
Total		120	100.0
Note: Unit of analysis: each AI prompt classified into one dominant Socratic question type N (example): 120 AI prompts across all dialogue cases			

Cognitive Levels of AI-Generated Prompts

The cognitive demand of AI-generated prompts was analyzed using the revised Bloom’s taxonomy. As shown in Table 2, the majority of prompts were concentrated at higher cognitive levels. The largest proportion of prompts was categorized under analysis (n = 30, 25.0%), followed by evaluation (n = 28, 23.3%), indicating that AI-mediated dialogue frequently encouraged learners to examine arguments, compare perspectives, and critically assess ideas. Prompts at the understanding level (n = 26, 21.7%) asked learners to explain concepts, while application (n = 14, 11.7%) and creation/synthesis prompts (n = 14, 11.7%) required learners to apply knowledge or integrate multiple perspectives. In contrast, only 6.7% (n = 8) of prompts focused on simple recall. Overall, the findings indicate that AI-generated questioning primarily stimulated higher-order cognitive engagement, particularly analytical and evaluative reasoning.

Table 2
Frequency of Cognitive Levels in AI Prompts (Cognitive Escalation)

Cognitive level	Descriptor in dialogue	Frequency (n)	Percent (%)
Remember / Recall	asks for facts or basic definitions	8	6.7
Understand	asks to explain concepts in own words	26	21.7
Apply	asks to apply concept to an example/context	14	11.7
Analyze	asks to compare, break down arguments, identify relationships	30	25.0
Evaluate	asks to judge, critique, weigh evidence, consider trade-offs	28	23.3
Create / Synthesize	asks to integrate perspectives into new position/model	14	11.7
Total		120	100.0
Note: each AI prompt coded by dominant cognitive demand (revised Bloom levels) N (example): 120 AI prompts			

Reflective Reasoning Activation

The analysis also examined reflective activation markers within AI-generated prompts to identify how conversational AI stimulated reflective reasoning during dialogue interactions. As shown in Table 3, the most frequent reflective trigger was assumption re-examination (n = 44, 46.3%), where the AI prompted learners to reconsider underlying beliefs or premises. This was followed by counterargument prompting (n = 38, 40.0%), encouraging learners to evaluate alternative viewpoints. Additionally, ethical or contextual constraint prompts (n = 29, 30.5%) invited learners to consider potential risks or unintended consequences. Other reflective markers included epistemic uncertainty prompts (n = 24, 25.3%), which highlighted knowledge limitations, and metacognitive self-check prompts (n = 21, 22.1%), encouraging

learners to reflect on their reasoning processes. These patterns indicate that AI-mediated dialogue frequently activated reflective and metacognitive thinking, supporting deeper intellectual engagement within the inquiry process.

Table 3
Frequency of Reflective Reasoning Activation Markers

Reflective activation marker	Example indicator	Frequency (n)	Percent of flagged prompts (%)
Assumption re-examination	“What assumption underlies...?”	44	46.3
Counterargument prompting	“What would a critic say...?”	38	40.0
Ethical / contextual constraint prompting	“What risks/unintended outcomes...?”	29	30.5
Epistemic uncertainty / limits	“What don’t we know...?” “What might be missing...?”	24	25.3
Metacognitive self-check	“How did you decide...?” “What led you...?”	21	22.1
Note: AI prompts containing reflective triggers (a prompt may include multiple markers)			
N (example): 95 prompts flagged with ≥ 1 reflective marker; multiple coding allowed			
Note: Because multiple coding is allowed, percentages can exceed 100% in total.			

Depth of Inquiry Chains

The depth of inquiry within AI-mediated dialogue was examined by analyzing the number of consecutive questionings turns within each dialogue episode. As presented in Table 4, most dialogue episodes demonstrated moderate to deep inquiry chains. The largest proportion of interactions fell within the moderate category (3–4 turns; n = 6, 33.3%), indicating clarification followed by an additional probing question. This was followed by deep inquiry chains (5–6 turns; n = 5, 27.8%), reflecting sustained probing across multiple Socratic questioning functions. Notably, very deep inquiry chains (7 + turns; n = 4, 22.2%) were also observed, where extended dialogue sequences involved reflective, evaluative, and synthesis-oriented prompts. Only a small proportion of interactions were categorized as short chains (1–2 turns; n = 3, 16.7%). Overall, the findings suggest that AI-mediated dialogue can sustain multi-turn inquiry processes, supporting extended cognitive scaffolding and deeper engagement in Socratic-style questioning.

Table 4
Frequency of “Inquiry Chain Depth” (Multi-turn Scaffolding Evidence)

Inquiry chain depth	Definition	Frequency (n)	Percent (%)
1–2 turns (short)	minimal probing; quickly shifts topic	3	16.7
3–4 turns (moderate)	clarification + one layer of probing	6	33.3
5–6 turns (deep)	sustained probing; multiple Socratic functions	5	27.8
7 + turns (very deep)	extended scaffolding; reflective + evaluative + synthesis	4	22.2
Total		18	100.0
Note: Each dialogue episode coded by maximum sustained inquiry chain depth (number of consecutive Socratic follow-ups on one concept before topic shift) and N (example): 18 dialogue episodes (across cases)			

Iterative Synthesis and Knowledge Construction

The analysis also examined synthesis-oriented prompts to understand how AI-mediated dialogue supported knowledge integration and argument construction. As shown in Table 5, the most frequent synthesis move was integration prompts ($n = 26$, 41.9%), where the AI encouraged learners to connect multiple ideas or perspectives. This was followed by trade-off balancing prompts ($n = 21$, 33.9%), which asked learners to evaluate benefits and risks when forming conclusions. Additionally, summative reframing prompts ($n = 19$, 30.6%) were used to restate learners’ positions and guide them toward clearer conceptual articulation. Other synthesis strategies included conditional conclusion prompts ($n = 14$, 22.6%), encouraging context-dependent reasoning, and model-building prompts ($n = 12$, 19.4%), which invited learners to propose frameworks or structured explanations. These patterns indicate that AI-generated dialogue frequently supported knowledge synthesis and integrative reasoning, enabling learners to consolidate ideas and develop coherent arguments through iterative inquiry.

Table 5
Frequency of Synthesis / Knowledge Construction Moves (Iterative Synthesis)

Synthesis move	Indicator	Frequency (n)	Percent of synthesis prompts (%)
Integration prompt	"Combine these ideas..." "How do these connect...?"	26	41.9
Trade-off balancing	"How would you balance benefits/risks...?"	21	33.9
Summative reframing	"So your position is..." then reframes	19	30.6
Model-building prompt	asks to propose framework/steps	12	19.4
Conclusion with conditions	prompts conditional conclusion ("under what conditions...?")	14	22.6
Note: AI prompts coded for synthesis moves (multiple coding allowed) N (example): 62 prompts flagged as synthesis-related.			

AI-Supported Socratic Inquiry Cycle

The Fig. 1. AI-supported Socratic Inquiry Cycle illustrates how conversational AI facilitates iterative inquiry by guiding learners through conceptual clarification, assumption testing, evidence evaluation, reflective reasoning, and knowledge synthesis, ultimately fostering critical thinking.

Discussion

The results of this research would be valuable in terms of the opportunities to operationalize the main aspects of the Socratic pedagogy in online learning through the generative AI chatbots. The semantic analysis of AI mediated dialogues showed that there are four mutually dependent dimensions of inquiry, including dialogic prompting architecture, cognitive escalation of questioning, activation of reflective reasoning, and iterative synthesis of arguments. These results show that conversational AI does not have to be a source of information only, but rather it can be used as a dialogic scaffold, which encourages higher-order thinking and reflective inquiry.

AI-Supported Socratic Dialogue and Classical Pedagogy

The initial significant observation is connected with dialogic prompting architecture that is present in AI-generated questioning patterns. The results revealed that, most of the time, the chatbot posed clarification questions, prompts based on assumptions and justification requests. The patterns of questioning are also quite similar to the classical Socratic method of inquiry, in which knowledge is built up through questioning as opposed to teaching. Socratic pedagogy focuses on the application of guided dialogue in order to provoke assumptions and provoke more conceptual thinking (Paul & Elder, 2007).

Equally, Ho et al. (2023) emphasize that Socratic questioning does contribute to the improvement of analyzing arguments and critically assessing ideas in learners. These insights have been expanded to the current findings that show that conversational AI systems can recreate these questioning structures in online settings. This is in line with current research indicating that generative AI could be used to realize classical pedagogical methods by being able to engage in a dialogue (Dickerson, 2024). Specifically, the recursive questioning patterns found in the dialogues can be attributed to the philosophical roots of Socratic questioning, in which the process of knowledge development takes place in the form of a repetitive sequence of questioning and contemplation instead of a passive reception of knowledge (Stamatellos, 2025). In addition, AI-generated questioning as dialogic is also reminiscent of wider theories of dialogic pedagogy, which highlight the importance of guided dialogue in facilitating intellectual engagement and collaborative meaning-making. Alexander (2008) and Wegerif (2013) argue that dialogic teaching motivates students to construct ideas, argue out points of view, and develop arguments by means of a conversation between themselves and the teacher. This study results indicate that conversational AI can apply such dialogic practices to internet-based learning environments, through the support of backward and forward questioning scenarios between learners and the AI systems.

Constructivist Learning and Cognitive Scaffolding in Human-AI Interaction

The second significant result is that of the cognitive escalation of inquiry as it is apparent in the dialogue sequences. It was found that AI-generated prompts slowly transitioned to explanatory and evaluative thinking. This developmental process is indicative of constructivist learning theory, whereby knowledge is built up by participating in active activities and more and more complicated mental activities. Constructivist theorists like Piaget (1972) highlight that learning takes place through cognitive restructuring processes whereby people develop new information by facing conceptual problems. By the same measure, the idea of the Zone of Proximal Development introduced by Vygotsky (1978) emphasises the need to implement scaffolds to help learners progress in their basic knowledge to higher levels of reasoning. The continuous questioning sequences that are witnessed in this research are similar to such scaffolding mechanisms where every prompt that was generated by AI was based on the responses that had been made before and progressively raised the cognitive load of the conversation. The results of the study also confirm the results of the studies about inquiry-based learning and problem-based pedagogy, which believe in the role of structured questioning as the process of cognitive development (Hmelo-Silver et al., 2007). The chatbot was effective in creating progressive enquiry because it maintained chains of multi-turn dialogue, through which learners were provided with increasingly complex levels of reasoning. Moreover, the ability of conversational AI to maintain such chains of inquiry identifies the possibility of AI technologies as adaptive cognitive scaffolds in digital learning settings. According to recent studies, generative AI systems have the potential to personalize feedback and provide learners with iterative reasoning and thus conceptual knowledge and problem-solving skills (Holmes et al., 2019; Kasneci et al., 2023).

Reflective Thinking and Metacognitive Reasoning in Human-AI Interaction

The other important study result is associated with the occurrence of reflective reasoning in AI-mediated conversation. The chatbot often created prompts that made learners question assumptions, consider counterarguments and interpret them in different ways. These mindfulness exercises served as metacognition cues that interrupted the linear thinking habits and promoted more intellectual activity. This trend can be compared to the epistemological principles of Socratic pedagogy whereby learning is realized by questioning what one believes and assumes to be true (Paul & Elder, 2007). Reflective questioning helps the learners analyze the reasonableness of the arguments and think over a variety of ideas, before making conclusions. These reflective procedures are the main focus of the acquisition of critical thinking abilities, which are broadly acknowledged as the key skills of modern higher education (Jamil et al., 2025).

Literature on AI-assisted learning settings has also led to the importance of generative AI in facilitating reflective learning. As an illustration, Raitskaya and Tikhonova (2025) believe that the human-AI dialogue would be capable of evoking metacognitive awareness as learners would be required to describe the process of reasoning and assess their arguments. On the same note, Santos-Guevara et al. (2026) discovered that Socratic dialogue with ChatGPT has a significant positive effect on student engagement and perception of learning in inquiry-based learning situations. This reflective destabilization apparent in the transcripts of the dialogues thus indicates that AI-mediated questioning can serve as an impetus to metacognitive growth, prompting the learners to go beyond the superficial answers to the deeper conceptual insight.

Artificial Intelligence as a Partner in Dialogic Knowledge Construction

The last emergent aspect of the results is associated with the iterative synthesis of concepts that is supported by AI chat. The chatbot became more and more supportive of the learner as the conversations evolved, and he was more willing to combine several points of view and come up with more sound arguments. These synthesis prompts mean that conversational AI can be used in the construction of knowledge in a collaborative way where learning is formed by dialogic exchange between a human and AI participant. This finding is consistent with the current research on the importance of human-AI joint learning ecosystems. According to Al Yakin et al. (2026), AI technologies are changing the nature of learning settings through new types of human-machine interaction to facilitate collaborative learning. On the same note, Deriba et al. (2026) underscore the fact that human-AI interface may create new dialogic relations that go beyond traditional pedagogical frames.

Pedagogically, this transition can be seen as a reflection of the changing trends of learning spaces towards cybergogy and Education 4.0 models, where digital technologies can be used to make the educational process interactive and learner-centered (Asad & Malik, 2023; Butt et al., 2020). In these systems, AI applications are not substitutes of teachers, but rather interactive cognitive collaborators that facilitate inquiry, reflection and integration of knowledge. The results of the research thus become part of the growing debates on the application of generative AI to higher education. Even though issues related to academic integrity and excessive reliance on AI still stand as critical factors of concern

(Cotton et al., 2024), the current findings show that AI systems may also be constructed in a positive way to encourage critical thinking and dialogic learning practices.

The Human-AI Dialogic Learning Ecosystem Model

To respond to the research question of conceptualizing the inquiry of AI, the results were used to design the Human-AI Dialogic Learning Ecosystem Model (Figure 2). The model demonstrates the way the conversational AI can be considered as a dialogic partner that enables Socratic inquiry and reflective learning in the digital worlds. This starts with the human learner posing inquiries by way of curiosity, prior knowledge and conceptual questions. Conversational AI, in its turn, uses the output of conversational AI to create Socratic prompts, including clarification, assumption probing, and evidence-seeking questions, that constitute the Socratic dialogue engine. In a series of questioning, a dialogic interaction loop has appeared as the learners have been involved in reflective reasoning and advancement of their ideas. This procedure corresponds to the studies regarding dialogic learning that focuses on constructing knowledge through the framework of a structured dialogue and collaborative reasoning (Alexander, 2008; Wegerif, 2013). Simultaneously, the reflective inquiry phase is representative of the principles of constructivist learning, in which scaffolding assists learners to advance to higher levels of cognition (Piaget, 1972; Vygotsky, 1978). In line with the recent research on AI-assisted learning environments, conversational AI has the ability to promote analytical thinking by encouraging the learner to review assumptions, discuss arguments, and synthesize various points of view (Favero et al., 2024; Fakour & Imani, 2025). Through the process of dialogue, learners had integration and synthesis of knowledge, which culminates in the learning outcomes of higher order such as critical thinking and intellectual autonomy. In this way, the suggested model expands the previous studies of AI-mediated learning in that it shows how Socratic pedagogy can be operationalized through generative AI in human-AI dialogic learning systems.

Conclusion

This paper discussed the possibilities of generative AI chatbots to support Socratic conversation and critical inquiry in the digital learning setting. The results indicate that the use of AI mediated questioning is capable of producing systematic Socratic prompts, which promote conceptual clarity, assumption checking and evidence-based reasoning. Conversational AI can lead learners into more intensive analytical thinking and synthesis of knowledge through a series of dialogues. The Human-AI Dialogic Learning Ecosystem Model presented postulates AI as a dialogic partner that facilitates reflective inquiry and higher-order thinking. Altogether, the research points out the possibilities of AI-mediated dialogue to revive Socratic pedagogy and encourage critical thinking in higher educational environments mediated by the digital approach.

Theoretical Contributions

The research paper is relevant to the field of artificial intelligence in teaching, as it combines traditional classical Socratic pedagogy and modern AI-enhanced learning platforms. These results indicate that generative AI chatbots can operationalize the most critical components of Socratic inquiry, including clarification questioning, assumption probing, and evidence-based reasoning, in the context of dialogue interactions between digital interlocutors, which ensures the extension of the theoretical background of dialogic pedagogy on the interaction between the teacher and the student (Paul & Elder, 2007; Dickerson, 2024). The research also supports the constructivist theory of learning by demonstrating that AI generated questioning acts as a type of digital cognitive scaffolding that helps learners to think at a higher level of analytical thinking (Piaget, 1972; Vygotsky, 1978). Also, the Human-AI Dialogic Learning Ecosystem Model proposed cryptic builds on the next generation theories of human-AI collaborative learning and dialogic knowledge building in Education 4.0 realms.

Practical Implications to Higher Education and AI-Assisted Pedagogy

The results have a number of implications in terms of applying generative AI in the teaching process in higher education. Dialogic learning can be achieved with the help of conversational AI devices as a type of learning assistant that helps inquiry-based learning using Socratic questioning and other analytical dialogue. Teachers can create learning experiences in which the students will interact with AI as inquiry partners but not as a source of information. The findings also provide the significance of efficient prompt design wherein conceptually rich prompts elicit more inquiry and thought process. In addition, Human-AI Dialogic Learning Ecosystem Model presents the pedagogical approach to integrating AI-mediated dialogue in seminars, reflective tasks, and problem-based learning exercises. Faculty training should also be invested in the institutions to help with the successful introduction of AI in digital pedagogy.

Limitations and Future Research Directions

In this research, a number of limitations exist which give guidelines as to the way future research should be done. To begin with, the analysis relied on the researcher-AI interactions which allowed them to examine Socratic patterns of questioning in a controlled manner, but not address the student participants. The next research should examine the way in which students interact with AI-mediated Socratic dialogue within the classroom. Second, the research was based on mainly qualitative analysis of the dialogue patterns instead of the evaluation of learning outcomes (i.e. the gains in critical thinking). To assess the effects of learning, future studies might take the form of an experimental or mixed-method study. Lastly, the 120-prompt, 18-episode of dialogue dataset might not be generalizable, and future research ought to increase the datasets and apply the Human-AI Dialogic Learning Ecosystem Model to other fields.

Declarations

Availability of Data and Materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interests

The authors declare that they have no competing interests.

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Clinical Trial Number

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Ethics Approval and Consent to Participate

Ethical approval for this study was obtained from the Institutional Research Ethics Committee of SZABIST University Larkana Campus. All participants provided informed consent before participation. Participation was voluntary, and all data were collected anonymously and treated confidentially in accordance with institutional ethical guidelines.

Consent for Publication

All participants provided informed consent for the publication of anonymized research findings. No identifiable personal information is included in this manuscript.

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Figures

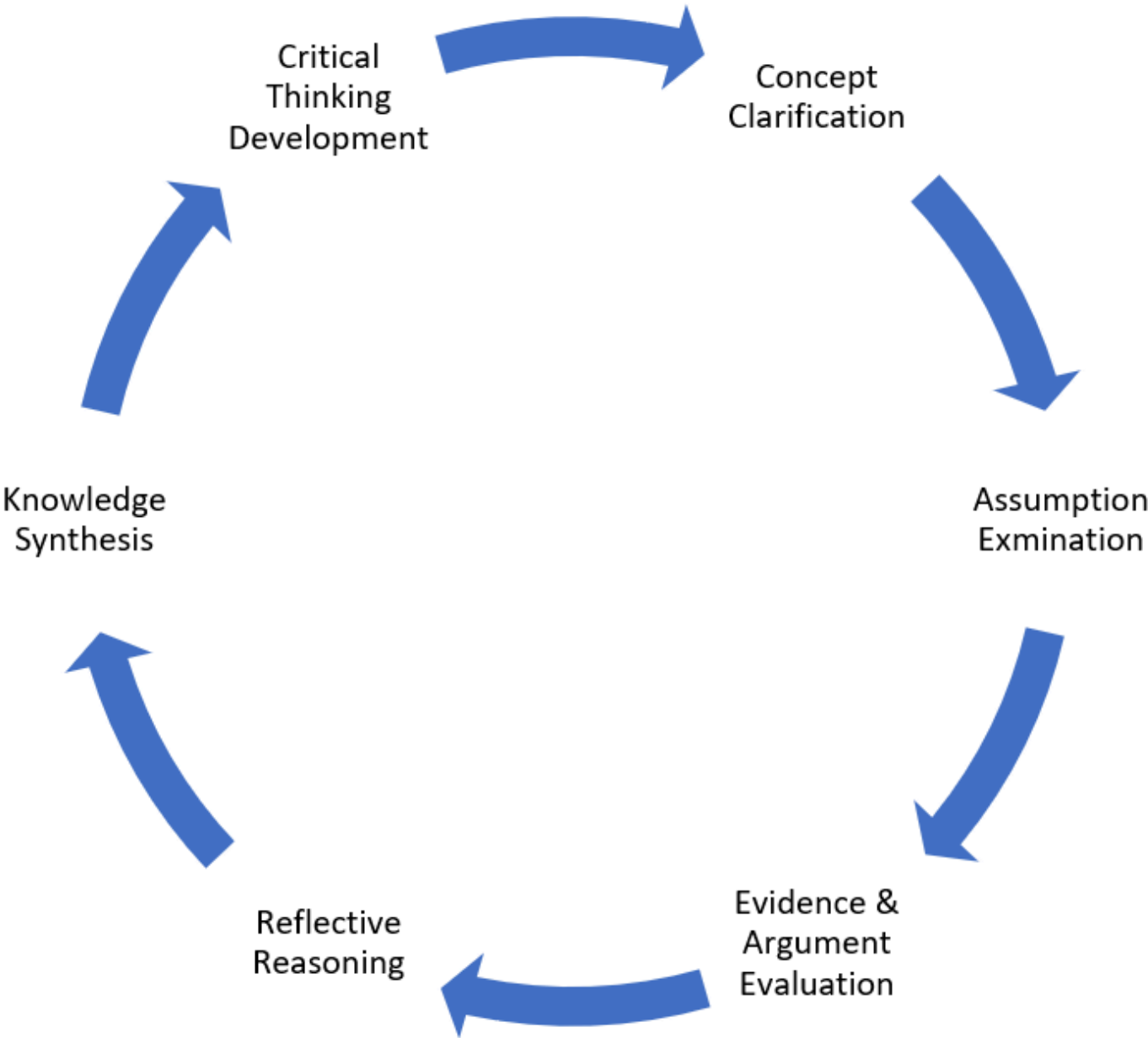


Figure 1

AI-Supported Socratic Inquiry Cycle

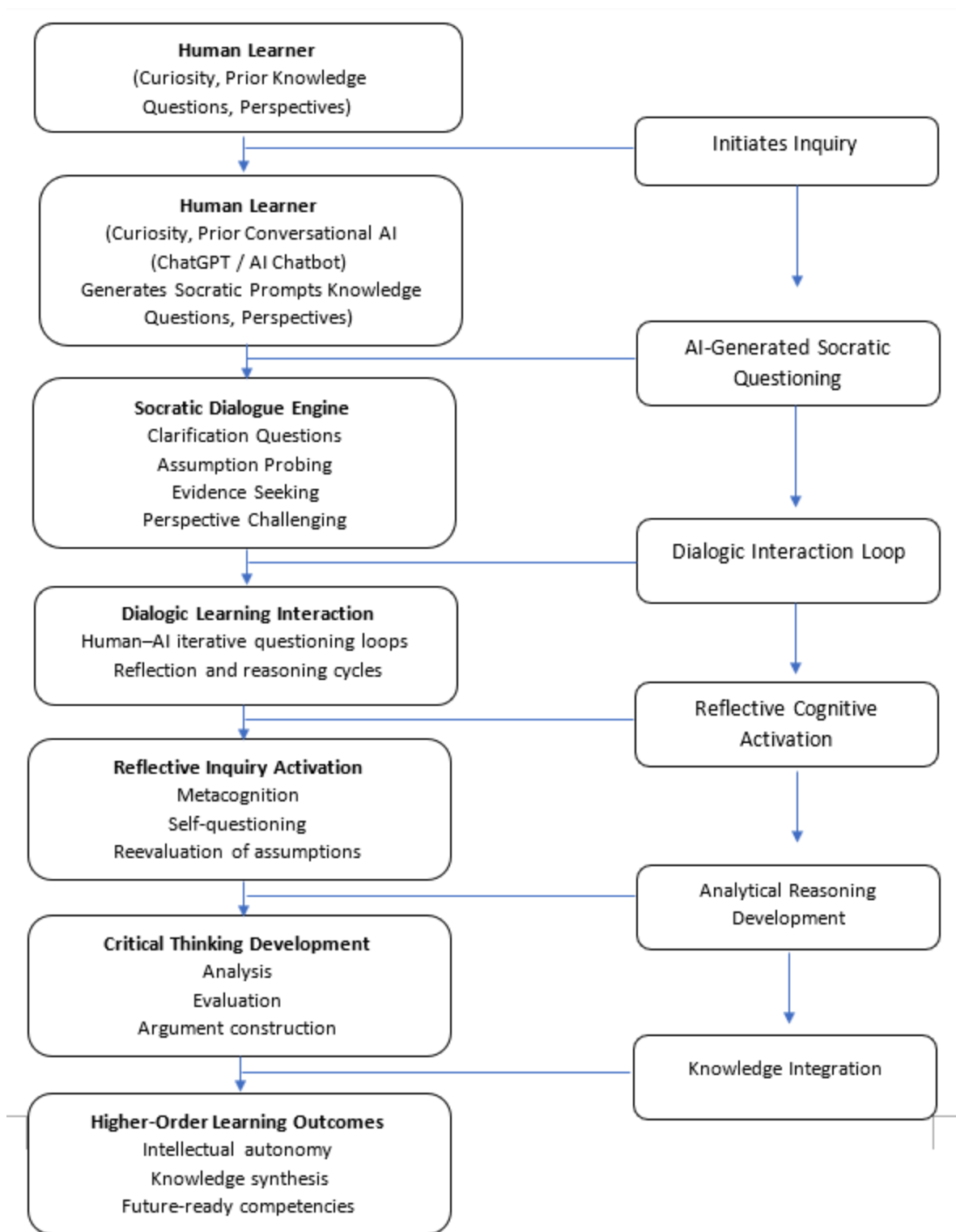


Figure 2

The Human-AI Dialogic Learning Ecosystem Model