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LARGE LANGUAGE MODELS AS SOCRATIC MENTORS: TRANSFORMING EDUCATIONAL APPROACHES FOR EPISTEMIC DEVELOPMENT

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Luiz G. Antunes[1], Brasilina Passarelli[2] and Sushila V. Claro[3]

ABSTRACT

This paper examines how Large Language Models (LLMs) can transform educational approaches by functioning as Socratic mentors rather than mere information providers. Drawing on dialogic pedagogy and constructivist learning theories, we propose a framework positioning LLMs as epistemological catalysts that emphasize epistemic agency, perspective multiplicity, and metacognitive development. The implementation of LLMs as Socratic mentors faces challenges including accuracy concerns, bias, transparency issues, and ethical considerations. Comparative analysis with traditional educational methods reveals potential advantages in personalization capabilities, scalability, and engagement potential. Future research should focus on evaluating impacts across diverse learner populations, balancing AI guidance with student autonomy, developing ethical integration frameworks, and investigating long-term epistemic development. This reconceptualization of LLMs as partners in intellectual exploration rather than substitutes for human thinking can enhance cognitive development while preserving uniquely human dimensions of education.

Keywords: Large language models. Socratic method. Epistemic development. Dialogic learning. Constructivism. AI education.

[1] University of São Paulo / School of Communications and Arts / Department of Public Relations, Advertising and Tourism and NACE USP School of the Future
author to whom correspondence should be addressed
ORCID: https://orcid.org/0000-0002-9474-8831
E-mail: radfahrer@usp.br
[2] University of São Paulo / School of Communications and Arts / Department of Library Science and Documentation and School of the Future NACE USP
ORCID: https://orcid.org/0000-0003-2949-7914
E-mail: linapassarelli2@gmail.com
[3] University of São Paulo / School of Communications and Arts / Department of Public Relations, Advertising and Tourism
ORCID: https://orcid.org/0000-0002-4165-6132
E-mail: sushila.claro@usp.br

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INTRODUCTION

Contemporary educational applications of digital technologies predominantly function within a "Question-Answering" paradigm that positions students as passive recipients of information rather than active participants in knowledge construction (UNESCO, 2023). This approach mirrors problematic tendencies within traditional educational systems that prioritize efficient information delivery over the development of critical thinking and epistemic capabilities. As Williamson (2023) argues, in knowledge ecosystems characterized by information abundance and rapid obsolescence, the ability to critically evaluate information, synthesize diverse perspectives, and adapt cognitive frameworks becomes more valuable than factual recall or procedural knowledge.

The emergence of advanced Large Language Models (LLMs) such as GPT-4 (OpenAI, 2023) and Claude (Anthropic, 2023) represents a potential paradigm shift in educational technology. While these technologies are predominantly deployed as information retrieval and question-answering tools, their transformative potential lies in their capacity to function as dialogic partners that challenge assumptions, introduce alternative perspectives, and scaffold metacognitive development (Kasneci et al., 2023).

THEORETICAL FOUNDATIONS AND PRIOR RESEARCH

Educational theorists have long recognized the limitations of transmission-based pedagogies. Freire's (1970) critique of the "banking model" of education emphasizes how traditional pedagogical approaches often position students as passive recipients rather than active co-creators of knowledge. Similarly, Bakhtin's (1981) concept of heteroglossia—the coexistence and interaction of multiple voices within discourse—offers a valuable framework for understanding how knowledge emerges through diverse perspectives.

Recent studies have demonstrated the efficacy of dialogic approaches in educational contexts. Mercer and Dawes (2021) show that dialogic teaching enhances cognitive development by exposing students to multiple perspectives and encouraging collaborative knowledge construction. Boyd and Markarian (2015) highlight the importance of what they term "dialogic stance"—an orientation toward teaching that prioritizes student voice, authentic inquiry, and the co-construction of knowledge.

Constructivist learning theory complements dialogic approaches by emphasizing active knowledge construction through cognitive adaptation and social negotiation (Piaget, 1952; Vygotsky, 1978; Bruner, 1996). Research by Hmelo-Silver et al. (2007) demonstrates

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that technology-enhanced constructivist environments can scaffold complex thinking skills effectively. Similarly, studies by Land et al. (2012) highlight the potential of digital tools to support knowledge construction by providing access to multiple information sources, facilitating collaborative discourse, and making thinking processes visible.

Despite extensive research on both dialogic pedagogy and educational technology, limited attention has been given to how LLMs might function as Socratic mentors. Recent work by Zhang et al. (2024) and Chen et al. (2023a) has begun to explore this potential, but comprehensive frameworks for reconceptualizing LLMs as dialogic partners rather than information providers remain underdeveloped.

RESEARCH GAP AND OBJECTIVES

While existing literature has examined various applications of LLMs in educational contexts (Yan et al., 2023; Zawacki-Richter et al., 2019), most approaches position these technologies as tools for information delivery, automated assessment, or content generation. Despite growing recognition of the limitations of this paradigm (Rudolph et al., 2023), there remains a significant gap in conceptualizing how LLMs might function as epistemic catalysts that support the development of higher-order thinking skills through dialogic engagement.

This paper addresses this gap by:

Proposing a conceptual framework that positions LLMs as Socratic mentors rather than information providersExamining implementation strategies across different educational contexts Identifying challenges and limitations of this approach Comparing the effectiveness of LLM-based Socratic mentorship with traditional educational methodsOutlining future research directions.

A FRAMEWORK FOR SOCRATIC LLM MENTORSHIP

Building upon existing research in dialogic pedagogy and constructivist learning theory, we propose a framework encompassing six essential functions for LLMs as Socratic mentors:

STRATEGIC QUESTIONING

Rather than providing direct answers, LLMs can pose thought-provoking questions that encourage students to examine assumptions, clarify concepts, and develop reasoned

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arguments. This approach stimulates higher-order cognitive processes such as analysis and synthesis, aligning with classic Socratic methods (Zhang et al., 2024). For example, instead of providing a definition of democracy, an LLM might ask, "What do you think are the essential characteristics of a functioning democracy?" followed by probing questions that deepen analysis.

PERSPECTIVE EXPANSION

LLMs can deliberately introduce alternative viewpoints on complex issues, helping students recognize the multidimensional nature of knowledge and avoiding simplistic conclusions or epistemic echo chambers. This function leverages the models' exposure to diverse perspectives while promoting intellectual humility and openness (Schramowski et al., 2022). For instance, when discussing economic policies, an LLM might present contrasting perspectives from different economic schools of thought.

EPISTEMIC SCAFFOLDING

Building on Vygotsky's (1978) concept of the zone of proximal development, LLMs can provide graduated assistance based on student needs, offering more support initially and gradually reducing guidance as students develop greater conceptual understanding and autonomy. This adaptive scaffolding can be particularly valuable in heterogeneous learning environments where students have different levels of prior knowledge and skill (González-Calero et al., 2024).

METACOGNITIVE MODELING

LLMs can demonstrate reflective thinking processes, encouraging students to monitor their own understanding and adjust learning strategies accordingly. By explicitly modeling metacognitive practices such as planning, monitoring, and evaluating learning processes, LLMs can help students develop self-regulatory capabilities essential for independent learning (Schraw & Moshman, 1995).

CONCEPTUAL MAPPING

LLMs can help visualize relationships between concepts for more integrated understanding, supporting students in connecting ideas across domains. This function

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addresses the common challenge of knowledge fragmentation by helping students develop coherent conceptual frameworks that facilitate knowledge transfer (Land et al., 2012).

EPISTEMIC VIRTUES CULTIVATION

LLMs can model intellectual virtues like curiosity, open-mindedness, and intellectual humility in their interactions with learners. By demonstrating these virtues in practice, LLMs can contribute to the development of dispositions that support effective inquiry and lifelong learning (Nye et al., 2023).

This framework transforms typical student-AI interactions from knowledge extraction to knowledge co-construction through dialogic engagement. Rather than positioning LLMs as authoritative sources of information, it reconceptualizes them as partners in intellectual exploration who support the development of epistemic capabilities through thoughtful dialogue.

IMPLEMENTATION STRATEGIES ACROSS EDUCATIONAL CONTEXTS

The implementation of LLMs as Socratic mentors requires context-specific adaptation across different educational settings. Below, we outline strategies for primary/secondary education and higher education contexts.

PRIMARY AND SECONDARY EDUCATION

In K-12 settings, LLMs can serve multiple functions aligned with developmental considerations:

Inquiry stimulators: LLMs can generate thought-provoking curriculum-related questions that spark curiosity and engage students in active inquiry. For example, in a middle school science class, an LLM might ask, "How might our city's climate change over the next 50 years, and what evidence supports your prediction?"Perspective brokers: LLMs can introduce alternative viewpoints suitable for developmental stages, helping students understand complex issues from multiple angles. This function is particularly valuable in social studies and language arts contexts where perspective-taking is a central learning objective.Thinking partners: LLMs can engage students in scaffolded dialogue that supports the development of critical thinking skills. For instance, when a student shares an initial analysis of a literary text, an LLM might respond with questions that prompt deeper consideration of literary devices, historical context, or character motivations.Reflection

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guides: LLMs can prompt articulation of thinking processes, helping students develop metacognitive awareness. By asking questions like "How did you approach this problem?" or "What strategies worked well for you?", LLMs can support the development of self-regulatory capabilities.

HIGHER EDUCATION

In undergraduate and graduate contexts, LLMs can serve as:

Socratic interlocutors: LLMs can facilitate sustained philosophical dialogue that explores complex concepts and theories in depth. This function is particularly valuable in humanities and social sciences where conceptual analysis and theoretical engagement are central.Interdisciplinary connectors: LLMs can highlight cross-disciplinary relationships, helping students integrate knowledge across traditional academic boundaries. For example, when discussing urban planning concepts, an LLM might draw connections to sociological theories, environmental science, and economic principles.Methodological guides: LLMs can support comparative analysis of knowledge production methods across disciplines, helping students understand epistemological differences and methodological approaches. This function can be particularly valuable in research methods courses and interdisciplinary programs.Research mentors: LLMs can assist with developing research questions and methodological design, providing feedback on research proposals and helping students refine their investigative approaches. While not replacing human mentorship, LLMs can provide additional support, particularly in resource-constrained environments.

FROM THEORY TO PRACTICE: EMERGING RESEARCH

Recent research demonstrates practical approaches to implementing LLMs as Socratic mentors. Zhang et al. (2024) developed SocraticLM, a language model specifically designed to engage students in thought-provoking dialogue rather than simply providing answers. Evaluation revealed that SocraticLM outperformed standard LLMs in teaching quality, significantly enhancing student engagement and conceptual understanding.

Similarly, Chen et al. (2023a) developed a "Dean-Teacher-Student" multi-agent pipeline that generated thousands of carefully designed Socratic teaching dialogues focused on mathematical problem-solving. This approach simulated authentic teaching scenarios by interacting with students in different cognitive states, strengthening teaching abilities crucial for effective Socratic mentorship.

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Richardson and Chadwick (2024) explored dialogic approaches to GenAI integration in secondary education through action research involving high school teachers. Their study positioned AI as a dialogic agent facilitating collaborative dialogue rather than an authoritative knowledge source, finding that this approach enhanced student engagement and critical thinking while reducing over-reliance on AI-generated content.

These studies suggest that the implementation of LLMs as Socratic mentors is not merely theoretical but can be realized through thoughtful design and implementation strategies that prioritize epistemic development over information delivery.

CHALLENGES AND LIMITATIONS

Despite the potential benefits of LLMs as Socratic mentors, significant challenges and limitations must be addressed for effective implementation.

ACCURACY AND RELIABILITY CONCERNS

LLMs sometimes produce incorrect or misleading information, particularly in specialized domains such as mathematics or science where nuanced understanding is essential. This "hallucination" problem poses significant risks in educational contexts where accurate information is crucial. Strategies to address this challenge include:

Implementing fact-checking mechanisms that verify LLM outputs against reliable sources Designing interfaces that clearly distinguish between factual statements and speculative or interpretive contentEducating students about the limitations of LLMs and developing critical evaluation skills

BIAS AND FAIRNESS ISSUES

LLMs trained on internet-scale data inevitably reflect and potentially amplify biases present in their training data (Schramowski et al., 2022). This can manifest as disproportionate representation of certain perspectives, reinforcement of stereotypes, or inequitable treatment of different student groups. Addressing bias requires:

Developing diverse and representative training datasets Implementing continuous monitoring and evaluation processes Designing systems that explicitly introduce perspective diversity Engaging diverse stakeholders in system design and evaluation

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TRANSPARENCY AND INTERPRETABILITY LIMITATIONS

The "black box" nature of large neural network models poses challenges for understanding how they arrive at particular outputs (Khosravi et al., 2022). This lack of transparency can undermine trust and accountability in educational contexts. Approaches to enhance transparency include:

Developing explainable AI techniques that provide insight into model reasoning Creating interfaces that make model processes more visible to users Implementing systems that allow students to interrogate model outputs

PRIVACY AND DATA SECURITY RISKS

The implementation of LLMs in educational contexts raises significant privacy concerns, particularly regarding student data (Pardo & Siemens, 2014). These systems typically require access to student inputs and potentially generate data about learning processes and outcomes. Addressing privacy concerns requires:

Implementing robust data governance frameworks Minimizing data collection to essential information Providing transparent information about data usage Ensuring compliance with relevant regulations (e.g., FERPA, GDPR)

SCALABILITY AND INTEGRATION CHALLENGES

While LLMs offer potential for scalable personalization, significant challenges exist in integrating these systems into existing educational infrastructures (Becker, 2000; Ertmer, 1999). Technical barriers, resource limitations, and institutional resistance may impede effective implementation. Addressing these challenges requires:

Developing user-friendly interfaces accessible to educators with varying technical expertise Creating implementation models that account for resource constraints Providing professional development and support for educators Designing systems that integrate with existing educational technologies

ETHICAL CONSIDERATIONS

The implementation of LLMs as Socratic mentors raises important ethical questions about the role of technology in education (Holmes & Porayska-Pomsta, 2022). Concerns include potential over-reliance on AI systems, impacts on human relationships in education, and questions of agency and autonomy. Addressing these concerns requires:

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Maintaining a clear focus on LLMs as supplements to, rather than replacements for, human teachingDesigning systems that enhance rather than diminish human agency Implementing ethical frameworks that prioritize student wellbeing and development Engaging in ongoing dialogue about the appropriate boundaries of AI in education

COMPARATIVE EFFECTIVENESS WITH TRADITIONAL METHODS

Evaluating the effectiveness of LLMs as Socratic mentors requires comparative analysis with traditional educational approaches across multiple dimensions.

PERSONALIZATION CAPABILITIES

LLMs offer unprecedented capabilities for personalization, adapting interactions to individual student needs, interests, and learning trajectories (Chen et al., 2023b). Traditional approaches often struggle to provide this level of personalization, particularly in resource-constrained environments with high student-teacher ratios. Research by Nye et al. (2023) demonstrates that well-designed LLM-based systems can provide more consistent personalization than typically available in traditional classroom settings.

However, the quality of personalization depends heavily on system design and implementation. Poorly designed systems may offer superficial adaptation that fails to address fundamental learning needs or may inappropriately track students into limited pathways based on initial performance.

ENGAGEMENT AND MOTIVATION

Research on student engagement with LLM-based systems shows mixed results. Studies by Bulut and Yildirim-Erbasli (2022) indicate that well-designed AI tutoring systems can enhance motivation through immediate feedback, personalized challenge levels, and reduced fear of judgment. However, other research suggests that prolonged interaction with automated systems may lead to decreased engagement compared to human interaction (Cavalcanti et al., 2021).

The effectiveness of LLMs in fostering engagement likely depends on implementation factors including interface design, interaction quality, and integration with broader learning activities. Systems designed specifically for Socratic engagement rather than information delivery show more promising results for sustained motivation (Zhang et al., 2024).

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DEVELOPMENT OF CRITICAL THINKING

Research on the impact of LLMs on critical thinking development remains limited. Traditional approaches emphasizing human dialogue and debate have established efficacy in developing critical thinking skills (Mercer & Dawes, 2021). While LLM-based systems designed for Socratic engagement show promise in this area (Chen et al., 2023a), longitudinal studies examining their impact on critical thinking development are needed.

Initial evidence suggests that LLMs may be particularly effective when they complement rather than replace human dialogue, providing additional opportunities for dialogic engagement that might not otherwise be available due to resource constraints.

SCALABILITY AND ACCESSIBILITY

LLMs offer significant advantages in scalability, providing consistent, on-demand dialogic engagement regardless of time or location (Caines et al., 2023). This capability addresses limitations of traditional approaches that depend on the availability of skilled human facilitators. In resource-constrained environments, this scalability may enable forms of dialogic engagement that would otherwise be inaccessible.

However, implementation costs and technical requirements may limit accessibility, particularly in under-resourced educational settings. The "digital divide" remains a significant concern, potentially exacerbating existing educational inequities if LLM-based approaches are not designed with accessibility in mind.

EDUCATIONAL OUTCOMES

Research directly comparing educational outcomes between LLM-based Socratic approaches and traditional methods remains limited. Studies by Zhang et al. (2024) show promising results for subject-specific outcomes, with students using SocraticLM demonstrating greater conceptual understanding than those using standard question-answering systems.

However, comprehensive evaluation requires assessment not only of subject-specific knowledge but also of epistemic capabilities, critical thinking skills, and metacognitive development. Longitudinal studies examining these broader outcomes are needed to fully evaluate comparative effectiveness.

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FUTURE RESEARCH DIRECTIONS

The implementation of LLMs as Socratic mentors opens numerous avenues for future research, spanning educational effectiveness, ethical implications, and technical development.

EVALUATING IMPACT ON DIVERSE LEARNER POPULATIONS

Future research should examine how different student populations respond to LLM-based Socratic mentorship. Key questions include:

How do factors such as prior knowledge, cultural background, and learning preferences influence engagement with LLM-based Socratic dialogue?What adaptations are necessary to ensure cultural responsiveness and inclusivity in LLM-based educational approaches?How can these systems be designed to address rather than exacerbate existing educational inequities?

This research requires mixed-method approaches combining quantitative assessment of learning outcomes with qualitative exploration of student experiences across diverse contexts.

BALANCING AI GUIDANCE AND STUDENT AUTONOMY

A critical area for future research concerns the appropriate balance between AI guidance and student autonomy. Key questions include:

How do different levels of AI scaffolding affect student agency and self-regulation? When and how should AI support be gradually reduced to promote student independence? What interaction designs most effectively encourage student initiative and creativity?

Longitudinal studies examining how this balance should evolve across different educational stages and contexts will be particularly valuable.

DEVELOPING ETHICAL AI INTEGRATION FRAMEWORKS

The ethical implications of LLM integration in education require ongoing research attention, particularly focusing on:

Frameworks for equitable AI access that address resource constraints and digital divides Governance structures that maintain appropriate human oversight of AI educational applicationsModels for transparency that effectively communicate AI capabilities and

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limitations to educational stakeholdersProtocols for identifying and addressing bias in AI-enhanced learning environments

This research should engage diverse stakeholders including educators, students, parents, policymakers, and technology developers to ensure comprehensive consideration of ethical implications.

INVESTIGATING LONG-TERM EPISTEMIC DEVELOPMENT

Perhaps most critically, future research should examine the long-term impact of Socratic AI mentorship on students' epistemic development. Key questions include:

How does sustained engagement with AI mentors affect students' epistemic beliefs and practices over time?Do AI-enhanced learning environments contribute to the development of critical thinking dispositions that transfer across domains?How do students transfer metacognitive strategies developed through AI interaction to other learning contexts?What complementary roles should AI and human mentors play in supporting long-term intellectual development?

Longitudinal studies tracking epistemic development across educational transitions will be essential for understanding these impacts.

CONCLUSION

The integration of Large Language Models as Socratic mentors in educational environments offers transformative potential to move beyond the limitations of traditional question-answering paradigms. By reconceptualizing LLMs as dialogic partners that challenge assumptions, introduce alternative perspectives, and scaffold metacognitive development, we can leverage these technologies to enhance epistemic development rather than simply deliver information efficiently.

The proposed framework for Socratic LLM mentorship emphasizes strategic questioning, perspective expansion, epistemic scaffolding, metacognitive modeling, conceptual mapping, and epistemic virtues cultivation. Implementation strategies across K-12 and higher education contexts demonstrate the practical applicability of this framework in diverse educational settings.

However, significant practical and ethical challenges remain, including accuracy and reliability issues, bias and fairness concerns, transparency and interpretability limitations, data privacy and security risks, scalability and integration challenges, and broader ethical

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considerations regarding the role of AI in education. Addressing these challenges requires ongoing research and development efforts focused on evaluating impact on diverse learner populations, balancing AI guidance with student autonomy, developing ethical AI integration frameworks, and investigating long-term epistemic development.

By reimagining LLMs as partners in intellectual exploration rather than substitutes for human thinking, educational systems can harness these technologies to enhance cognitive development while preserving the uniquely human dimensions of effective education. The future of AI in education lies not in automating traditional pedagogical approaches but in transforming educational paradigms to prioritize critical thinking, epistemic agency, and metacognitive development in an increasingly complex knowledge landscape.

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