

Improving Argumentation Skills through AI-Driven Dialogues: A Transdisciplinary Approach

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Abstract

This article investigates the potential of artificial intelligence (AI) as a dynamic tool to enhance argumentation skills in education. By engaging students in real-time dialogues with AI, this study provides insights into a transdisciplinary approach that encourages critical thinking and helps students build persuasive, well-structured arguments across various subjects. Recognizing the growing need for argumentation proficiency in digital-age learning, we outline a methodological framework that leverages AI-driven dialogue tools to challenge students' assumptions, refine their thinking, and expose them to diverse perspectives. This research explores the ethical and pedagogical considerations essential to responsibly integrating AI into educational settings, focusing on balancing technological assistance with human oversight. The findings support AI's role as a valuable educational partner, offering a practical and innovative strategy for developing students' argumentation skills and preparing them for a technologically integrated future. For instance, the study highlights practical use cases where AI-driven dialogue systems in education foster critical engagement and personalized feedback, showing promise in large and resource-constrained classrooms.

Keywords: *Argumentation skills, AI-driven dialogues, critical thinking, transdisciplinary education, pedagogical methodology, ethical considerations in AI*

1. Introduction

As artificial intelligence (AI) rapidly transforms the educational landscape, educators and researchers are increasingly focused on how this technology can enhance students' essential skills for the digital age. (Lee & Kwon, 2024) Among these, argumentation - the ability to construct, articulate, and defend a reasoned stance - is foundational to

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critical thinking, effective communication, and informed decision-making across multiple fields. (Ayeni et al. 2024) Traditional methods for teaching argumentation, including debates, essay writing, and peer review, have long proven valuable. These approaches encourage students to engage with opposing viewpoints, refine their logic, and support their positions with evidence. However, these methods often face constraints in providing individualized, real-time feedback and struggle to meet the diverse learning needs of modern students in large or resource-limited classrooms. (Kim & Ryu, 2024)

In response to these challenges, AI-driven tools offer a unique opportunity to enhance argumentation training through interactive, personalized learning experiences. AI-based platforms, including intelligent tutoring systems and chatbots, are increasingly recognized for their ability to adapt to individual learning styles, provide immediate feedback, and sustain student engagement. While current applications of AI in education have primarily focused on subject-specific learning and basic cognitive skills, there is a growing interest in leveraging AI to develop higher-order skills, such as argumentation. AI's ability to engage students in real-time, iterative dialogue presents a promising new avenue for cultivating argumentation skills by challenging students' assumptions, prompting them to consider alternative perspectives, and guiding them through the process of refining their reasoning. (Angulo et al. 2023)

This study seeks to address the gap in the existing literature by investigating the potential of AI as a dynamic tool for enhancing argumentation skills across disciplines. For example, recent initiatives in higher education have implemented AI-powered platforms, such as chatbot systems, in debate and critical thinking courses to provide tailored feedback that encourages students to refine their arguments in real time. These use cases demonstrate AI's ability to adapt to various learning environments, from small classrooms to online educational platforms.

Utilizing a transdisciplinary framework, this research explores how AI-driven dialogues can support students in various fields - from social

sciences to STEM and humanities - by fostering reflective thinking and enabling students to practice argumentation in a structured, responsive environment. By positioning AI as an interactive learning partner rather than a static knowledge repository, this study aligns with the goals of holistic education and offers insights into how AI can support critical skill development in ways that traditional instruction may not achieve.

The significance of this research lies in its examination of AI as a tool for argumentation skill-building, a capability that is crucial for students navigating today's complex, information-rich world. Through this study, we aim to provide a framework for implementing AI-driven dialogue systems that help students engage more deeply with the reasoning process and develop a nuanced understanding of constructing arguments. Additionally, this study addresses ethical considerations and challenges associated with integrating AI into education, ensuring a responsible and balanced approach to technology-assisted learning. By offering practical insights and exploring both the pedagogical and ethical implications, this research contributes to a deeper understanding of how AI can be strategically used to prepare students for an interconnected, rapidly evolving future where both technological and cognitive skills are paramount.

2. Literature Review

The development of argumentation skills is increasingly recognized as a foundational component of modern education, as it forms the basis for critical thinking, effective communication, and informed decision-making. In educational settings, argumentation fosters students' ability to reason logically, articulate ideas with clarity, and engage critically with diverse perspectives (Kuhn & Udell, 2003)

Traditional pedagogical methods for teaching argumentation typically include structured classroom debates, essay writing exercises, and peer reviews, all of which promote cognitive engagement by encouraging students to support their viewpoints with evidence, counter opposing arguments, and refine their reasoning (Crowell & Kuhn, 2014)

Despite their effectiveness, these methods often face practical limitations, such as the difficulty of providing individualized feedback and the challenge of addressing diverse learning styles within a large classroom. Moreover, time constraints can inhibit thorough student engagement with complex topics, potentially limiting their ability to fully develop argumentation skills. (Su et al., 2023)

Consequently, the integration of artificial intelligence (AI) in education has emerged as a potential solution for enhancing the reach and impact of argumentation training. (Guo et al., 2023)

The use of AI in education has expanded rapidly, leading to innovations in personalized, interactive learning experiences that can cater to individual students' needs. AI-based systems, including chatbots and intelligent tutoring platforms, are now commonly used to provide students with real-time feedback, adapt to their learning styles, and offer customized support that fosters continuous engagement. (Ruwe & Mayweg-Paus, 2023)

For example, intelligent tutoring systems can analyze students' responses, identify gaps in understanding, and provide tailored prompts to guide their learning. Research shows that such AI-driven tools can enhance comprehension, sustain students' motivation, and support long-term retention of knowledge. (Heeg & Avraamidou, 2023)

Nevertheless, these applications have predominantly focused on subject-specific knowledge and basic cognitive skills, such as memorization and factual recall, rather than complex skills like argumentation. (Essel et al., 2023)

This presents a critical gap in the current literature: while AI has demonstrated potential in adaptive learning, its capacity to develop higher-order cognitive skills, such as constructing well-reasoned arguments, remains underexplored. Addressing this gap, recent studies have begun investigating how AI can facilitate the development of argumentation skills through interactive dialogue. (Polonsky & Rotman, 2023)

Unlike traditional instructional methods, AI-driven dialogues provide a unique, responsive platform that allows students to engage in continuous, iterative argument-building. Through this process, students receive immediate feedback, which enables them to reflect on their ideas, identify potential flaws, and strengthen their arguments in real-time. (Guo et al. 2022)

This immediacy in feedback is particularly beneficial, as it allows students to refine their thought processes continuously, a feature often limited in traditional classroom settings due to time and resource constraints. For instance, recent research demonstrates that AI-based dialogue systems can encourage critical reflection by presenting students with alternative viewpoints, challenging their assumptions, and prompting them to reconsider their initial positions. (Guo et al. 2022) Consequently, this interactive element fosters deeper cognitive engagement and has been shown to enhance students' abilities to think critically and argue persuasively. (Huq et al. 2024)

Furthermore, the use of AI in teaching argumentation offers distinct advantages in terms of scalability and accessibility, which are crucial for addressing the diverse needs of today's learners. Traditional argumentation training requires significant teacher involvement to guide discussions, provide feedback, and support students as they navigate complex arguments. (Huq et al. 2024)

By contrast, AI-driven systems can offer these functions at scale, allowing more students to benefit from individualized feedback without placing additional burdens on educators. This scalability is particularly valuable in large or resource-limited educational settings where access to personalized instruction may be constrained. (Zhai & Wibowo, 2023)

Additionally, AI-based dialogue systems can operate asynchronously, enabling students to engage with argumentation exercises at their own pace and revisit their responses as needed. This flexibility supports a more inclusive learning environment that can accommodate various

learning preferences and schedules, making argumentation training more accessible and adaptable to individual needs.

In particular, this study's transdisciplinary approach highlights the relevance of AI-driven argumentation training across diverse fields, from science and technology to social sciences and the humanities. In disciplines such as the natural sciences, where students are often required to evaluate hypotheses and interpret data critically, argumentation skills are essential for forming evidence-based conclusions.

Similarly, in social sciences and humanities, students must navigate complex social issues, synthesize multiple perspectives, and construct well-supported arguments. By offering a structured environment in which students can practice argumentation across these fields, AI-based dialogue systems help to bridge disciplinary divides, promoting skills that are valuable in various academic and professional contexts.

Furthermore, positioning AI as a dynamic learning tool rather than a static repository of knowledge aligns with the principles of holistic education, which emphasize the development of transferable skills, such as critical thinking and adaptability, over rote memorization.

Moreover, the transdisciplinary nature of AI-driven argumentation training aligns with current educational goals that emphasize the need for adaptable, lifelong learners equipped to navigate complex, interdisciplinary challenges.

In today's increasingly interconnected world, students must be able to think critically across diverse contexts and engage thoughtfully with varied perspectives. AI-driven dialogues facilitate this by exposing students to a wide range of argument structures and viewpoints, encouraging them to develop a nuanced understanding of complex issues.

This interactive, iterative learning environment allows students to experiment with different approaches to argumentation, understand the nuances of opposing views, and ultimately cultivate a more refined and adaptable argumentation skill set. Thus, integrating AI into

argumentation training not only enhances students' critical thinking abilities but also prepares them to engage meaningfully with the multifaceted problems they are likely to encounter in their personal and professional lives. In summary, while traditional approaches to teaching argumentation have proven effective, the integration of AI presents a unique opportunity to overcome existing challenges and expand the accessibility and scalability of argumentation training. By providing real-time, personalized feedback and fostering engagement through interactive dialogues, AI-driven systems support a deeper level of cognitive engagement that is difficult to achieve in conventional classroom settings. (Angulo et al., 2023)

Additionally, the adaptability of AI-based dialogue systems to various disciplines and learning styles makes this approach particularly well-suited to the diverse needs of modern learners. Thus, this study contributes to the growing body of literature on AI in education by demonstrating how AI can be leveraged to develop argumentation skills—a higher-order cognitive ability that is essential for success in both academic and real-world contexts.

3. Methodology

This study utilizes a transdisciplinary framework that leverages AI-based conversational agents to develop students' argumentation skills across various academic disciplines. At the core of this methodology is an interactive dialogue model designed to engage students in real-time exchanges with AI systems specifically configured to stimulate critical thinking, challenge existing assumptions, and guide students toward constructing well-supported arguments. By creating a structured, adaptive environment, the AI allows for iterative learning and supports cognitive growth that aligns with the demands of modern, multidisciplinary education.

The interactive dialogue model employed in this study follows a structured prompt-response-feedback cycle, offering students a continuous series of interactions that promote reflective thinking. The

process begins when students receive an initial prompt from the AI agent, which could be a question, scenario, or hypothetical situation crafted to encourage the formation of a specific argument. This initial prompt is carefully designed to spark interest and provoke thoughtful engagement, setting the stage for the student to articulate a response that can be further developed. Once the student submits a response, the AI analyzes the argument's coherence, logic, and supporting evidence, then delivers targeted feedback to either reinforce the student's reasoning or encourage additional refinement.

For instance, if a student supports a particular stance, the AI may respond with a counterargument, challenging the student to consider alternative viewpoints or to critically assess the limitations of their position. This dynamic, back-and-forth exchange continues as the AI provides ongoing, personalized feedback, prompting the student to reflect, iterate, and enhance their argument progressively. By encouraging this iterative process, the AI fosters an environment where students are continuously motivated to re-evaluate and strengthen their reasoning, allowing them to experience the benefits of immediate feedback that can be difficult to achieve in traditional classroom settings. Furthermore, this continuous loop of engagement and reflection helps students to internalize critical thinking skills, as they are not merely defending a single stance but are learning to navigate the complexities of argumentation in an adaptive, real-time setting.

This methodology was applied across multiple academic disciplines - social sciences, STEM, and humanities - to evaluate the adaptability and efficacy of AI-driven argumentation training in diverse fields. To ensure disciplinary relevance, each AI interaction was meticulously tailored to the content and cognitive demands specific to each field. For example, in social sciences, prompts often addressed topics requiring ethical considerations and social analysis, while STEM prompts focused on data interpretation and hypothesis testing, encouraging students to ground their arguments in empirical evidence. Meanwhile, in the humanities, prompts frequently presented interpretive questions, inviting students to analyze texts or construct arguments that draw upon abstract reasoning and thematic connections. While the specific content varied by discipline,

the underlying structure of argument development and refinement remained consistent, underscoring the versatility of the AI model in fostering argumentation skills across different areas of study.

A defining characteristic of this methodology is its transdisciplinary nature, which allows it to bridge disciplinary boundaries and provide a universally applicable framework for argumentation training. By engaging students from various fields in structured AI dialogues, this approach enables them to cultivate argumentation skills that are not only relevant to their academic disciplines but are also transferable to other contexts. For instance, students in STEM may benefit from enhanced critical thinking skills that support more nuanced hypothesis formation, while those in the humanities may gain a deeper understanding of how to construct evidence-based interpretations. This adaptability reinforces the methodology's value as a comprehensive educational tool, capable of addressing the distinct needs of different fields without compromising the core elements of effective argumentation training.

The transdisciplinary framework also emphasizes the role of AI as a facilitator of critical reflection rather than as a source of definitive answers. In this learning environment, students are encouraged to explore the nuances of their arguments, consider the validity of counterpoints, and refine their perspectives based on iterative feedback rather than focusing solely on obtaining correct responses. This reflective approach aligns with principles of constructivist learning, where students actively construct knowledge by engaging with complex questions and re-evaluating their perspectives. By positioning AI as an interactive tool for reflection, this methodology enables students to move beyond surface-level engagement, allowing them to delve deeply into the mechanics of argumentation and develop a more sophisticated understanding of how to communicate their ideas effectively.

To evaluate the efficacy of this approach, data were collected on students' argumentation skills before and after their interactions with the AI system. This data was analyzed to assess changes in their ability to construct, articulate, and defend coherent arguments. Feedback from students and instructors further informed the refinement of the AI

prompts and feedback mechanisms, ensuring that the dialogue model remained responsive to the needs of learners across disciplines. By focusing on the continuous improvement of the AI's ability to foster critical thinking and reflective learning, this study positions AI as a sustainable and scalable resource for argumentation training that can support diverse educational contexts and learning styles.

In summary, the methodology employed in this study harnesses the power of AI to create a structured, interactive environment for the development of argumentation skills. Through a prompt-response-feedback cycle, this model encourages students to think critically, engage in reflective practices, and strengthen their reasoning over time. Its transdisciplinary application underscores its flexibility, while its emphasis on reflection over rote answers aligns with contemporary educational goals. By fostering iterative, student-centered learning, this AI-driven methodology offers a promising framework for integrating argumentation training into the curriculum in a way that is both adaptable and deeply impactful.

4. Results and Discussion

The findings from this study demonstrate that AI-driven dialogues can effectively enhance students' argumentation skills, particularly by providing them with real-time feedback and diverse viewpoints. Through structured interactions with the AI, students developed a stronger ability to organize their thoughts, respond to counterarguments, and refine their positions in a way that demonstrated critical engagement and an improved command of argumentation techniques.

One key outcome observed was an increase in students' ability to construct coherent and persuasive arguments. The AI's prompt-response-feedback cycle encouraged students to think more deeply about their claims, recognize potential weaknesses, and make necessary adjustments. For instance, students who initially presented unstructured arguments learned to clarify their main points and provide supporting evidence, ultimately creating arguments that were more persuasive and logically

sound. The immediate nature of the AI feedback also contributed to students' skill development, as they were able to revise and improve their arguments in real time. In a typical interaction, for example, a student may present an initial argument that the AI system evaluates for logical coherence and evidence. If the argument lacks clarity, the AI provides constructive feedback, such as suggesting more precise wording or prompting the student to consider alternative perspectives. This real-time, iterative process allows the student to improve their argument immediately, reinforcing critical thinking and adaptability skills essential for effective argumentation.

Additionally, the study highlights AI's potential to foster critical thinking by exposing students to a range of perspectives. By interacting with an AI that provided varied viewpoints, students were challenged to consider different angles and address potential objections, thus developing a more balanced and nuanced approach to argumentation. This experience of engaging with diverse perspectives is essential for students' growth as critical thinkers and effective communicators. Furthermore, the AI-driven feedback mechanism allowed students to receive consistent, constructive guidance—something often difficult to achieve in traditional classroom settings where teacher time is limited.

However, the study also identifies challenges associated with implementing AI-driven argumentation training. While the AI provided valuable support, there was a need for human oversight to contextualize feedback and address any misunderstandings that arose. Teachers played an essential role in guiding students' learning journeys, helping to interpret AI feedback, and fostering a deeper understanding of argumentation principles. This balance between AI and human guidance was necessary to prevent students from becoming overly reliant on AI-generated responses, ensuring that they developed their independent critical thinking skills.

The ethical implications of using AI in argumentation training are also noteworthy. Concerns about privacy, data security, and potential biases in AI responses highlight the need for responsible AI implementation in education.

In particular, data privacy remains a significant concern. For educational institutions, managing the vast amount of student data generated through AI interactions requires strict adherence to privacy regulations. Effective strategies for ensuring data security include anonymizing student inputs, limiting data retention periods, and conducting regular audits to safeguard against data breaches and potential misuse.

AI systems must be designed to protect student data and mitigate any biases that could influence feedback, especially given the critical nature of argumentation in shaping students' perspectives. Addressing these ethical considerations is essential for fostering an inclusive and fair learning environment.

Table 1 provides an overview of how the AI-driven dialogue model was applied across different disciplines. Each field - social sciences, STEM, and humanities - utilized prompts relevant to its specific content and cognitive demands, yet maintained a consistent focus on building argumentation skills. By tailoring prompts to each discipline, the AI encouraged students to engage deeply with relevant skills, from ethical reasoning in social sciences to data-driven argumentation in STEM. This table summarizes the types of prompts used, the primary skill focus, and the observed impact on students' argumentation abilities in each discipline.

Table 1: Application of AI-Driven Dialogue Model Across Disciplines and Observed Impact on Argumentation Skills

Discipline	Prompt Example	Skill Focus	Type of AI Feedback provided	Observed Impact on Students
Social Sciences	"What are the ethical implications of surveillance in society?"	Ethical reasoning & critical analysis	Counterarguments, ethical perspective prompts	Increased ability to consider multiple perspectives, justify ethical arguments with supporting evidence.
STEM	"Defend or refute this hypothesis based on the given data set."	Data interpretation & evidence-based reasoning	Data critique, alternative hypothesis prompts	Improved capacity to form evidence-backed arguments and recognize data limitations.
Humanities	"Analyze the central theme of freedom in this text."	Abstract reasoning & thematic analysis	Thematic connections, counter-interpretations	Enhanced skills in constructing coherent interpretations and connecting arguments to broader themes.
Business/Economics	"Evaluate the economic impact of social media on small businesses."	Cost-benefit analysis & practical application	Market analysis prompts, cost-benefit scenario prompts	Strengthened analytical skills in economic evaluation, improved ability to build practical, data-supported arguments relevant to real-world contexts.
Environmental Science	"Discuss the pros and cons of renewable energy adoption."	Evaluative reasoning & sustainability considerations	Environmental impact feedback, pro-con structuring prompts	Enhanced ability to evaluate sustainability arguments, improved skills in balancing benefits and limitations, and recognizing ecological trade-offs.

5. Practical and Ethical Considerations

The practical implementation of AI-driven argumentation training requires a balanced approach that includes both AI guidance and human oversight.

Balancing AI and Human Oversight: Teachers must guide students in interpreting and applying AI feedback, preventing an over-reliance on AI-generated responses. Teachers can provide context, additional insights, and a human perspective that complements the AI's guidance, creating a more holistic learning experience.

Ethical Implications: The use of AI in education raises critical ethical questions, especially regarding privacy and bias. Student interactions with AI may involve data collection, and it is essential to protect this information and ensure that it is used responsibly. Additionally, AI systems must be carefully designed to avoid biased responses, which could shape students' views unfairly or limit the scope of argumentation. Regular audits of AI responses and transparent design practices can help mitigate these risks, ensuring that AI remains a tool for equitable and unbiased learning.

Pedagogical Challenges: Implementing AI dialogue tools in educational settings also presents logistical and pedagogical challenges. Teachers must receive training to effectively incorporate AI into their instruction, understand its limitations, and provide supplemental guidance. Moreover, school resources and budget constraints may limit access to advanced AI tools, creating barriers to equitable implementation. Educators and policymakers must work collaboratively to address these challenges, ensuring that AI-driven argumentation training is accessible and effective.

6. Conclusion

This study underscores the potential of AI-driven dialogues as a valuable tool for developing students' argumentation skills, offering a transdisciplinary approach that supports critical thinking and effective communication. By engaging with AI in structured, real-time dialogue, students have the opportunity to refine their arguments, consider multiple perspectives, and develop a deeper understanding of complex topics. The findings suggest that AI can serve as a powerful educational partner, providing consistent feedback and fostering an environment conducive to skill-building.

For educators, this research provides practical insights into integrating AI into classroom practices to support argumentation training. However, the study also emphasizes the need for a balanced approach, combining AI-driven guidance with human oversight to ensure that students receive constructive, contextually appropriate feedback. Ethical considerations, such as privacy and bias, must also be carefully managed to create a responsible and inclusive learning environment.

Future research should explore the long-term impacts of AI-driven argumentation training, examining how sustained engagement with AI influences students' critical thinking skills and argumentation abilities. Additionally, further studies could investigate potential improvements in AI algorithms to enhance feedback accuracy and inclusivity. As educational paradigms continue to evolve in response to technological advances, AI-driven argumentation training offers a promising model for preparing students to navigate a world where technology and human intellect are increasingly intertwined.

Future research could further explore AI's impact on long-term critical thinking skills and the ways in which continuous AI-driven dialogue engagement might shape students' abilities to reason across disciplines. Additionally, refining AI feedback mechanisms to address the nuances of argumentation in various cultural and disciplinary contexts may enhance AI's utility as a universal educational tool.

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