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Using AI-driven Conversational Agents to Support Student-Led Collaborative Scientific Inquiry

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Abstract: This study explores leveraging AI conversational agents for student learning that are responsive to the data privacy concerns and pedagogical needs of public schools. We articulate how our agents are developed and trained, student experiences with and feedback on the agent capabilities, and some of the ethical considerations our team has wrestled with regarding how and why to integrate AI agents into game-based, narrative-centered learning.

Introduction and background

The design of AI-driven conversational agents for education has garnered skyrocketing interest due to their potential in augmenting and improving student learning (Labadze et al., 2023). Previous work on intelligent agents has shown how this technology can support students' scientific inquiry practices and metacognition in collaborative science learning (White et al., 1999; Biswas et al., 2005). However, the integration of generative AI brings a host of ethical concerns to the design of conversational agents, including a lack of reliability and accuracy in responses (e.g., "hallucinations"), a lack of transparency in how tools may use and store student data, and an increasingly unsustainable reliance on high-cost, power-hungry models that negatively impact the environment (Kasneci et al., 2023; Selwyn, 2022). Moreover, learning scientists interested in designing AI chatbots for learning are faced with the dual challenge of navigating the messy economic and political contexts in which AI tech companies seek to influence students and teachers (Williamson & Enyon, 2020), as well as understanding the nuanced ways in which different integrations of AI can influence unfolding learning processes. To navigate these challenges, we draw on practical, sustainable approaches to agent model development to explore how AI-driven conversational agents can be designed to fill targeted, student-centric roles in narrative-centered, collaborative learning environments. This study addresses the question: How do AI-driven conversational agents influence collaboration and inquiry in a narrative-centered educational game?

Design

Our work draws inspiration from work on intelligent agents designed to fill pedagogical roles such as supportive tutor (Graesser et al., 2018), collaborative inquiry facilitator (Dyke et al., 2013), teachable peer (Biswas et al., 2005), and knowledge building partner (Gerard et al., 2024). Rather than leveraging existing tools such as ChatGPT, which require significant processing power, our team designed conversational agents that were built on a smaller language model and tailored to particular story-relevant character roles. Our conversational agents draw on FLAN-T5-small (Chung et al., 2024), a language model that uses a modest number of parameters (80 million vs. 175 billion in GPT-3; Brown et al., 2020). This means our agents are using significantly less computational resources to respond to student inquiries than if ChatGPT answered. While the usage of a smaller language model is not necessarily innovative for a computer science audience, from a human-centered design perspective, creating sustainable, efficient, and specialized AI-driven conversational agents is a vital goal for AI education research. Importantly, our approach considers the data privacy and pedagogical needs of classrooms, where the hallucination of inaccurate or harmful responses by an AI chatbot can be problematic for learners. Our approach leverages curated, human-crafted responses as a training database, so that the agent model uses AI computational power to determine which response to provide, allowing students to ask questions using natural language, but the actual response text seen by the student is human-written and vetted. This blend of AI power with human intelligence provides us with conversational agents that teachers can trust, which can respond to students' freeform questions with curated and pedagogically-supportive responses. Our team has built seven conversational agents that are each integrated into a particular game character with a distinct pedagogical role and specific content knowledge integrated. The game, called SciStory: Pollinators, allows students to explore concepts about community food systems, pollinator ecosystems, and food justice in the context of an open-ended socio-scientific narrative. Students explore a community garden and gather evidence to convince the town mayor of the

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garden's importance for the neighborhood. Our presentation will unpack three pedagogical roles the agents fulfill: 1) providing feedback on students' evidence-based arguments, and 2) guiding scientific inquiry with open-ended questions, and 3) answering direct questions about science content and gameplay.

Methods

Data are drawn from pilot tests of SciStory: Pollinators with students both in and out of school (Humburg et al., 2024). Group 1 is a 5th-grade classroom (n=18) in the U.S. Midwest, and Groups 2 is 8th graders attending a summer camp in the U.S. South (n=21). Each group first had a brief discussion about AI and conversational agents. Students then played the demo game in groups of three on laptops for 1-1.5 hours. Students also engaged in open-ended inquiry by controlling virtual bees in the [project] mixed-reality environment (Danish et al., 2022), which was embedded in the narrative game as a mini-game evidence-gathering experience. After the playthrough, students participated in whole group discussions about the AI-driven features in the game and shared design ideas for how they would improve the game's conversational agents. Log file data was collected for each student to record their in-game interactions, in particular their interactions with AI-driven characters and the game actions they took in response to the characters' feedback and answers. Video and audio data were collected as students played together. Through a multimodal combination of thematic analysis of video data (Braun & Clarke, 2012) and qualitative log file analysis of student-agent interactions from a discursive analytic lens (e.g., next-turn proofs; Sacks et al., 1974), our analysis will demonstrate how student learning in this narrative-centered game context is influenced by different kinds of interactions with AI agents.

Results and discussion

Our analysis found promising preliminary results demonstrating that three different types of CAs–argumentation revision, science inquiry, and question-answering agents–fostered students' collaboration and inquiry. First, the argumentation revision agents facilitated students to reflect on their answers and integrate multiple perspectives. In one episode, a student pitched some ideas about gardens to the argumentation agent and received feedback that the student should provide more evidence, refine his answer, and submit it again. This response from the agent led to a conversation with group members. The student's groupmate read the submitted argument, and they collectively reflected on what the student might have missed in his answer. The groupmate then suggested including additional evidence to his answer by saying, "Why don't you talk about trees and carbon dioxide?". This encouraged the student to search for other relevant scientific information and revise his argument.

The question-answering agent promoted student collaboration during learning activities by helping students identify tasks, distribute work, and gather information. For instance, one student asked the question-answering agent what to do next, and the agent responded that students should talk to every character in the game to collect more information. This response led the group to adjust their strategies to navigate the game, with exchanges like, "Oh okay, so you have to talk to the mayor, Watson, and then find evidence to convince him," and "Talk to everybody, then go to the mayor." Recognizing the need to coordinate efforts, the group then began to share their progress (e.g., "I'm already with Elliot. You have to talk to everyone and take notes," and "You two go to the Food lab while I handle the Garden.") In this way, the question-answering agent effectively enhanced student collaboration by helping learners establish a shared understanding and negotiate strategies to achieve their learning goals together.

Finally, the scientific inquiry agent facilitated students' progress between cycles of inquiry with information and ideas for what to try next in the virtual bee mini-game. For example, one student asked the agent, "What is the most dangerous thing to a bee?" The agent responded, "... pollution can hurt bees by making it harder for them to smell flowers and find nectar. They can get lost and confused if the air is thick with smog." This response answered the student's question and encouraged students to investigate further to see how pollution hurts bees. One student said, "We did not go to the parking lot." Another student added, "The parking lot has cars and cars have gasoline and there are chemicals in gasoline." Two students clapped their hands, and together they decided to check what would happen to bees in the parking lot. In this example, the agent's response served as a good resource for facilitating students' transition to a new inquiry task.

The overall goal of this study is to better understand how interactions with AI-driven characters guide students towards meaningful learning moments during the exploration of socioscientific narratives. Our poster will explore the hypothesized design features of agents that support students' progress along their open-ended inquiry. We will also highlight stumbling blocks and features of the AI agents that students struggled with as avenues for future design and improvement of tailored conversational agents for scientific inquiry. By exploring both our design of conversational agents and the ways students interacted with these agents in the context of their open-ended inquiry, our poster will provide implications for the ethical and sustainable technological design of AI agents to support the kinds of rich, student-led inquiry that we know to be meaningful for learning.

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