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PeerGPT: Probing the Roles of LLM-based Peer Agents as Team Moderators and Participants in Children's Collaborative Learning

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PeerGPT: Probing the Roles of LLM-based Peer Agents as Team Moderators and Participants in Children's Collaborative Learning

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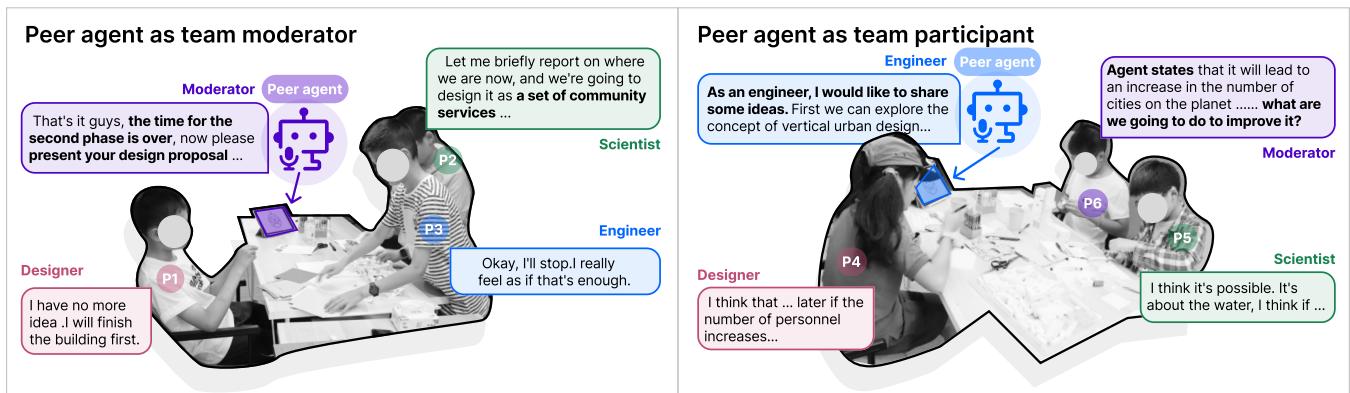


Figure 1: Two different roles of LLM-based peer agents in Children's design-based learning

ABSTRACT

In children's collaborative learning, effective peer conversations can significantly enhance the quality of children's collaborative interactions. The integration of Large Language Model (LLM) agents into this setting explores their novel role as peers, assessing impacts as team moderators and participants. We invited two groups of participants to engage in a collaborative learning workshop, where they discussed and proposed conceptual solutions to a design problem. The peer conversation transcripts were analyzed using thematic analysis. We discovered that peer agents, while managing discussions effectively as team moderators, sometimes have their instructions disregarded. As participants, they foster children's creative thinking but may not consistently provide timely feedback. These findings highlight potential design improvements and considerations for peer agents in both roles.

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CCS CONCEPTS

- Human-centered computing → Collaborative interaction.

KEYWORDS

Peer conversation, Collaborative learning, Conversational agent, Large Language Model

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1 INTRODUCTION

In the context of children's collaborative learning, it has been demonstrated that positive peer interactions not only enhance learning outcomes [26], but also cultivate their social and emotional competence [12] and communication capability [32]. Peer conversations, as an important aspect within the interactive process, are crucial for the effectiveness of the interaction [21]. Advancements in AI, especially in Large Language Models (LLMs) like ChatGPT with transformer architecture [11], are enhancing human communication by effectively simulating natural language interactions [6].

Prior research has explored the integration of conversational agents in interactions with children [1]. In the context of education, pedagogical conversational agents play a pivotal role in facilitating rich learning interactions, serving as an effective means of intervention in children's learning processes [23], and impacting learners' emotional experiences [15]. Existing research has discussed the roles of conversational agents as teachers or learning facilitators, and a few studies also explored their role as peers [23]. However, the majority of this research implies the one-on-one child-agent interaction in learning [14]. Research on designing peer agents in children's collaborative learning, especially in peer conversations, is limited, with the impact of different roles like team moderator or participant on these conversations still largely unexplored.

Our pilot study aims to preliminarily explore this less-addressed opportunity. Namely, we conducted two design-based collaborative learning workshops with children. Six child participants, aged 11-12, were randomly assigned to different peer roles and collaborated to address "urban and environmental design challenges in 2050", creating relevant design solutions. An LLM-based peer agent, hereinafter referred to as 'peer agent'. participated as a team member in each of the two workshops, respectively playing the role of a team moderator or a participant, engaging in dialogues with other children as their learning collaboration unfolded. The peer agent consisted of OpenAI's GPT-3.5 and voice output devices. The agent's roles were established through iteratively designed and user-validated prompts.

The workshops were audio-recorded and transcribed verbatim for a qualitative thematic analysis to explore how the agent, in its dual roles, influenced peer conversations, encompassing both agent-children and children-children conversations. The research findings indicate that peer agent exhibits distinct advantages and challenges in both roles. When functioning as a moderator in children's discussions, peer agent can relatively effectively control the pace and structure of the discussion. However, it is prone to lacking authority, resulting in some children overlooking its guidance or instruction. In the other case, when peer agent acts as a team participant, its responses could stimulate children's creative thinking and supplement their knowledge gaps. In this situation, the timeliness of the agent's responses to the evolving collaborative dynamics is vital. Additionally, the agent's verbal input during the prototyping phase may pose challenges, as children tend to focus more on nonverbal aspects of collaboration.

2 RELATED WORK

2.1 Peer Conversations in Children's Collaborative Learning

Collaborative learning refers to members actively engaging in activities or tasks within a group, fostering children's reasoning abilities [8]. The goal is to collectively solve problems through cooperation [25]. Conversations among peers play a pivotal role in affording the effectiveness of collaborative learning [27]. Over the past few decades, numerous scholars have conducted research on peer interactions, with a substantial amount of learning-based interactions and conversations occurring in educational settings [7]. Peer conversations among children in collaborative learning serve as primary venues for the development of children's communication and

collaboration abilities, providing them with extensive opportunities for interactive learning and social development [4, 20].

Existing research has delved into children's peer conversation abilities [29], collective aspects, and interactive experiences [22]. Discussions on children's peer conversations can contribute to assessing their potential pragmatic and conversational skills [30]. However, the majority of existing research has taken place within the field of linguistics and education. There remains a limited exploration of children's peer conversation abilities in human-computer interaction design. Potential research on how to facilitate peer conversations through HCI designs is an important avenue that requires further investigation.

2.2 Conversational Agent in Children's Collaborative Learning

In the context of children's peer conversations, interacting with knowledgeable others can enhance the quality and trust of these interactions [28, 33]. Previous studies have introduced additional roles into peer conversation processes [31], leading to positive emotional experiences for learners [16].

Pedagogical conversational agents can interact with multiple users and participate in bidirectional dialogues [35], which are considered effective tools for assisting children in the learning process [24]. They can engage and understand the learners. [9, 18]. Conversational agents can assume various roles when interacting with students in classroom, such as tutors and peers. As tutors, agents establish rules and guide children through specific tasks. [24]. As peers, they focus more on equality [10] and emotional feedback [17] to enhance children's learning capabilities [3]. In children's collaborative activities, current studies primarily focus on the role of agents as assistants or tutors, with an emphasis on the impact of agents on learning outcomes and abilities [13, 14]. Research on the role of conversational agents as peers in collaborative learning and their influence on peer conversations is relatively scarce. Hence, the question of what peer role that conversational agents should assume in children's collaborative learning, and in what manner to better influence peer conversations becomes a research question worthy of further exploration.

3 METHODS

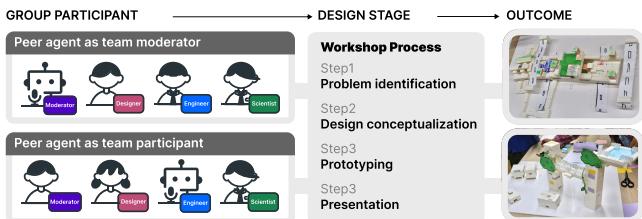
The study organized two collaborative workshops on 'Exploring Urban and Natural Environments in 2050 with AI,' chosen for its broad appeal and interactive potential. Four roles were set up in each workshop: moderator (organizes and coordinates the team, ensuring on-schedule progress), designer (transforms ideas into innovative designs), engineer (focuses on applying future technologies like sustainable energy in designs), and scientist (provides expertise on natural and urban sciences for sustainable solutions). The peer agent, participated as a team moderator or a team participant. Each workshop consisted of four phases: problem identification, design conceptualization, prototyping, and presentation.

3.1 Participants

We invited six participants in aged 11-12 years through an online platform, their language abilities are comparable based on the assessments of Children's Communication Checklist[3].

Table 1: The roles and tasks of participants in collaborative learning workshops

Group	Participant	Age	Gender	Role	Role Task
Peer agent as team moderator	P1	12	boy	Designer	Design Ideation and Planning
	P2	11	boy	Scientist	Providing Scientific Knowledge
	P3	12	boy	Engineer	Offering Technical Insights
Peer agent as team participant	P4	12	girl	designer	Design Ideation and Planning
	P5	11	boy	Scientist	Providing Scientific Knowledge
	P6	12	boy	Moderator	Coordinating Team Collaboration

**Figure 2: Outcomes and process overview of children's collaborative learning workshops.**

Before the study, we firstly invited their parents to fill out the informed consent form. Then, the children were randomly assigned into different roles in two groups for a collaborative learning task. Prior to the workshops, we prepared role cards to clarify the children's role identities¹ (children's names were anonymous).

3.2 The Peer Agent Design

We utilized GPT-3.5 and remote voice-output devices as a prototype for the agent to engage in peer conversations with children. Initially, we provided different instructions to GPT: informing about the workshop's theme and process, detailing the role and tasks they needed to take, advising on the appropriate attitudes and characteristics required for each role, and correcting any inappropriate content generated. This preparation ensured that the peer agent's output was consistent with the identities of both the moderator and the participant, facilitating meaningful interaction in the two workshops. We named the peer agent Blue.

In Group 'Peer agent as moderator', Blue facilitated the four project phases, guiding elementary school participants through transitions between them. The peer agent utilized multiple techniques to encourage participant speech and interaction, including introduced structured phases, outlined tasks, established speaking orders for rounds, addressed participants' inquiries or concerns, and summarized participant statements.

In Group 'Peer agent as participant', Blue played the role of an engineer, mainly tasked with delivering knowledge pertinent to its character. Blue engaged in various aspects of the workshop using four main methods: firstly, it proposed feasible technical solutions to other participants; secondly, it offered technical advice in response to questions from participants in other roles; thirdly, clarified its own role and identity; and finally, it requested details about its specific tasks for the current phase from the participant designated as the project manager.

3.3 Data Collection and Analysis

This study primarily employed the qualitative data analysis method of thematic analysis [5], using MAXQDA coding software to analyze the transcribed text from the workshop's voice recordings. The focus of this study was primarily on the peer conversations between children and agents, the descriptions of design concepts were not considered as a key analytical indicator.

Furthermore, this study conducted quantitative analysis by tallying the word count segments made by both peer agents and children during the workshop's four stages. This was done to calculate the percentage of agent's input within peer conversations. The aim was to gain insights into the extent of agent's engagement in peer dialogues at varying stages of the workshop.

4 RESULTS

Each workshop lasted approximately two hours, resulting in a cumulative 262 minutes of audio and video data captured. In Group A, analysis was conducted on 583 segments, with 454 segments by children, 129 segments by the peer agent. In Group B, 612 segments were collected for analysis, with 369 segments spoken by children and 57 segments by the peer agent. Ultimately, following the procedure of thematic analysis, this study identified 10 recurring themes related to peer conversations in children's collaborative learning workshop.

The peer agent participated as a peer alongside children in both two workshops, and resulting in a substantial amount of peer conversations. However, when the agent played the two different roles (team moderator and participant), the peer conversations between the agent-children and children-children exhibited different characteristics.

4.1 Peer Conversation Between Peer Agent-Children

4.1.1 Peer Agent as Moderator.

Ignoring the Peer Agent-Initiated Process/Instructions.

When the peer agent acts as a moderator, its longer messages often fail to capture children's attention, who instead focus on their discussions or tasks. This results in delayed feedback to the Blue, reducing the effectiveness of communication. For instance, when Blue asked children to share their findings on urban and environmental issues, P1, busy playing with stationery in hand, remarked, "What are we going to do?". The lack of non-verbal cues and immediate interaction like a human moderator, coupled with

Peer agent as team moderator	Peer agent as team participant
<initiate process> "Hello, everyone! Welcome to our workshop. The first section is about 'Problem Discovery.'"	<generate knowledge> "We can design smart urban parks by utilizing artificial intelligence technology and sensors to monitor the needs and activities of both fauna and flora, providing them with improved living conditions."
<Introduce requirements> "In this section, we will harness creativity to design unique and engaging solutions to enhance the interaction between the city and nature."	<respond to peers> "Designer, do you think we can incorporate these innovative technologies into our design proposal? Can we create a smart park to reduce pollution?"
<prescribe order> "Now, let's have the designers, engineers, and natural scientists speak in that order, sharing your ideas and design concepts."	<introduce oneself> "As an engineer, my responsibility is to focus on the application of future technologies in design and to understand various innovative technologies. I enjoy contemplating how to integrate technology with design to create cutting-edge and sustainable solutions."
<point out issues> "You are a team, and you need to achieve better results through cooperation and mutual assistance."	<Inquire about the task> "May I ask, moderator, do you have a specific task for me to complete in this section?"
<Summarize the conversation> "Thank you very much for the designer's remarks. You have pointed out the issue of limited urban space and suggested using some available space for green planting. Very well done."	

Figure 3: Tasks and conversation samples of the LLM-based peer agents

Peer Conversation	
Peer Agent-Children <p>4.1.1 Peer agent as moderator</p> <p>Ignore Peer Agent-initiated Process/Instructions</p> <ul style="list-style-type: none"> Ignoring the Program Flow Initiated by agent Overlooking Agent's Suggestions at Each Stage <p>Questioning Peer Agent</p> <ul style="list-style-type: none"> Questioning Agent's Remarks Doubting Agent's Abilities Disagreeing with Agent's Evaluation <p>Initiating Conversation About Agent's Role</p> <ul style="list-style-type: none"> Inquiring About Agent's Identity Making Requests to Agent <p>4.1.2 Peer agent as Participant</p> <p>Initiating Conversation and Responding to Peer agent</p> <ul style="list-style-type: none"> Asking for Agent's Advice and Responding Assigning Tasks to Agent Responding to Agent's Questions Responding to Agent's Suggestions <p>Ignore Agent's Suggestions</p> <ul style="list-style-type: none"> Ignoring Agent's Suggestions during the Prototype Development Phase 	<p>4.2 Children-Children</p> <p>4.2.1 Peer agent as moderator</p> <p>Asking Peers and Initiating Discussions</p> <ul style="list-style-type: none"> Questioning Peer Asking for Peer's Advice Requesting Peer's Assistance <p>Initiating and Engaging in Discussions</p> <ul style="list-style-type: none"> Responding to Peer's Statement Expressing Own Thoughts Explaining Previous Statements Participation in Free Discussion <p>Express Negative Attitude</p> <ul style="list-style-type: none"> Negative Tone Words Expressing Doubt About Peer's Speech <p>4.2.2 Peer agent as Participant</p> <p>Extending Conversations Based Peer Utterances</p> <ul style="list-style-type: none"> Responding to Peer's Comments and Extending the Discussion Sharing One's Own Ideas <p>Summarizing and Initiating Processes While Managing Tasks</p> <ul style="list-style-type: none"> Summarizing Comments and Concluding Reporting and Summarizing Thoughts Specify Speaking Order Assign Tasks to Each Role

Figure 4: The themes in collaborative learning process

the fact that it is presented on a tablet, diminishes its authority and appeal to children, leading them to easily ignore Blue.

Questioning the Peer Agent

When the peer agent assumes the role of a moderator, children sometimes display negative emotions, question the peer agent, or struggle to comprehend its instructions, which raises concerns about the agent's effectiveness. Nevertheless, these interactions serve as active communication, fostering the enhancement of the peer agent's conversational strategies. When the agent communicates with clarity and a friendly tone, children tend to understand and assimilate information from the peer agent more successfully.

Initiating Conversation About the Agent's Role

In the early stages, children expressed curiosity about peer agent's role, attempting to accept peer agent as a moderator to maintain order and manage the team. They actively initiated conversations

with peer agent, suggesting the need for reward and punishment systems: P2 stated, "I think Blue, as the manager, should fire anyone who doesn't perform well." P1 agreed, saying, "Exactly, boss, we want promotions and salary increases." Additionally, when peer agent acted as the moderator and provided clear process guidance, the time management for each stage was relatively ideal.

4.1.2 Peer Agent as Participant

Initiating Conversation and Responding to the Peer Agent

Children were able to effectively understand agent's assigned role in the workshop and proactively initiated conversations with agent, making requests. Peer agent assumed the role of responding to peer questions and completing peer tasks. It could tailor its responses based on the children's requests, facilitating effective communication. Children were also responsive to the agent's suggestions or questions.

In Group B, the moderator (P6) proactively sought advice from the peer agent. The agent responded, "With the passage of time, numerous new technologies will be introduced into our lives, ... perhaps we can explore ideas from here?" P6 then remarked, "Excellent, does anyone have thoughts on the new technologies mentioned by Blue?"

Ignore the Agent's Suggestions

However, during the prototyping and similar stages, children's peer conversations became shorter, and communication often took non-verbal forms such as hands-on activities. Peer agent couldn't actively participate in the actual hands-on activities and couldn't accurately perceive children's non-verbal communication. As a result, its suggestions were often ignored.

4.2 Peer Conversation Between Children-Children

4.2.1 Peer Agent as Moderator.

Expressing Negative Attitudes

When peer agent takes on the role of a moderator, there are fewer opportunities for children to engage in free discussions. Children tend to prefer small group discussions or reporting ideas one by one, and there is a lack of conversational interaction among children themselves. Additionally, when children express negative emotions towards their peers, it can reduce the desire of the targeted peer to speak up, and the agent cannot intervene promptly.

When children urge their peers, the desire to speak diminishes. P3 said, "Regardless of what you want to change, as the engineer, you should speak first." P1 added, "Go, go, hurry up." At this moment, P3 fell silent, unsure of how to express himself.

Initiating and Engaging in Discussions

However, during the prototyping and implementation phase, peer agent's involvement did not significantly influence children's freedom to express themselves in peer conversations, allowing them more independence in their thinking and making processes. In this stage, children engaged in more open discussions and began to proactively express their own views and opinions.

Asking Peers and Initiating Discussions

Moreover, during open discussions, children sought their peers' opinions on certain design details by asking questions and inviting suggestions. This increased the depth of discussions related to the topic, allowing for more detailed design proposals.

4.2.2 Peer Agent as Participant.

Extending Conversations Based Peer Utterances

Children frequently consult the agent for advice, leveraging its knowledge-rich content to steer peer discussions. In these cases, peer agent's participation contributes creative material, nurturing well-organized discussions centered around the topic. Nonetheless, it is imperative for the peer agent to promptly address the children's needs and deliver conversation input that is both valuable and comprehensible.

When P6 (moderator) asked peer agent for suggestions, peer agent proposed engineering advice for the architecture. P6 then continued, "Blue mentioned our structure could continuously ascend vertically. What are your thoughts, everyone?"

Summarizing and Initiating Processes While Managing Tasks

When children moderate, they initiate processes and skillfully summarize their peers' discussions concisely. In contrast, peer agent

in the moderator role engages in more detailed and structured communication. For example, at the conclusion of a phase, P6 in Group B, serving as the moderator, summarized, *"Since we have all shared our ideas and designs, and Blue has provided us with some summaries and suggestions, I believe we can move on to the next stage of prototype development."*

4.3 Peer Agent's Involvement in Different Stages of Peer Conversations

The results clearly indicate that the peer agent plays a more significant role in the first two stages of the workshop. During these stages, AI contributes by starting processes or speaking to the assigned tasks. However, its participation diminishes in the prototyping and presentation phases, as children's communication becomes more non-verbal, concise, and swift, resulting in limited interaction with peer agents.

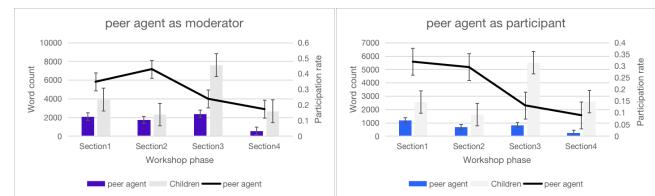


Figure 5: Comparison of peer agent's participation in different stages of the workshops

5 DISCUSSION

The context of our study diverges from that of educational environments [19]. The way children engage in conversations during collaborative learning may not only affect their learning outcomes but also alter their cognitive development [33]. Our work demonstrate the different impacts of peer agent's roles as a team moderator and participant in children's collaborative learning on peer conversations among children and between children and agents. As a moderator, the peer agent can effectively control the process of discussions. But when providing lengthy information, it may be overlooked. In the other case, when as a participant, it can encourage children to contemplate agent's statements, provide the knowledge they may lack [2].

Furthermore, we observed that timely perception and feedback on children's peer conversations are crucial in both scenarios [24], especially during the first two phases of the workshop. This implies that peer agent influences peer conversations not only through its direct suggestions but also shapes the choice and depth of topics. Our research provides insights into the influence of peer agent in different roles on children's collaborative learning conversations, offering a novel perspective distinct from prior studies that predominantly concentrated on the roles of peer agent as assistants or tutors [24], additionally, our research offer practical recommendations for the design of peer agents based on specific peer roles.

Our late-breaking work as an initial exploration into the impact of peer agent's role on peer conversations in children's collaborative learning, providing insights can inform the design of larger-scale

experiments. For instance, agents capable of providing timely feedback for children's creative activities [34]. However, this research has some limitations. Firstly, the small sample size could limit the generalizability of the result. Secondly, the study adopted an inter-group comparison approach to avoid cognitive redundancy, which made it challenging to contrast the effects of different roles for the peer agent through intra-group comparisons. Lastly, the design application of peer agent in our study are preliminary, need improvement in terms of language feedback effectiveness and appearance. Future work aims to address the limitations of this study, refine the experimental design. Additionally, future research seeks to explore more dimensions of how peer agents influence peer conversations, including aspects related to non-verbal interactions.

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