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# Exploring the Design of Pedagogical Agent Roles in Collaborative STEM+C Learning

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## Supplementary Materials

### Study Protocol

We conducted case study interviews with three students and two teachers to identify agent features and design principles, audio-recording all conversations. The five participants varied in race and gender (Black, White, Hispanic; male, female), spoke fluent English, and had prior experience with C2STEM. Students were aged 16-17, and teachers had 15-20 years of teaching experience. Each 45-minute session presented participants with two video scenarios (2-4 minutes each) showing different student dyads encountering difficulties with the Truck Task. In the first scenario, students struggled to update position and velocity variables at each simulation step, using a fixed value instead of the kinematic equation. In the second, the truck moved backward due to an incorrect lookahead distance (i.e., when the truck must begin decelerating to stop at a stop sign).

For each scenario, participants watched the video uninterrupted and then reviewed it to answer a series of questions (discussed shortly). To inform the design of the teaching agent, we asked teachers to describe how they identified student difficulties and would implement appropriate interventions to help the students. For the peer agent, we asked students to specify their preferences for how a peer agent should detect challenges and intervene effectively. During the interviews, teachers and students responded to five questions: 1) Where do students first encounter difficulty? 2) Why did you choose this point? 3) Where should an intervention be administered (if at all)? 4) Why this intervention point? and 5) If an intervention is required, how should it be administered? These questions were designed to provide detailed insights into how each agent should detect difficulties, interact with students, and time interventions—critical elements for defining effective feature sets for pedagogical agents. All interviews were semi-structured, enabling participants to elaborate and engage in follow-up discussions.

### Codes

Our analysis resulted in thirteen codes, presented with definitions, frequencies, and utterance examples in Table 1. Each utterance received an average of two codes, resulting in 176 total codes across all 88 utterances. Codes are sorted by total code occurrence across teacher and student utterances.

**Table 1**
*Codes (continued on next page)*

| Code | Description | Example |
|---|---|---|
| **Data Synthesis**<br>n=33, p=0.19, t=0.55, s=0.45 | Analysis of data informing intervention decisions or detecting student difficulties (e.g., discourse, environment actions). | "...it was just a question on which block they are bringing over…" |
| **Intervention Initiation**<br>n=21, p=0.12, t=0.29, s=0.71 | Who should trigger agent intervention (agent or student)? | "I feel like the agent should almost be able to kind of intervene..." |
| **Domain Knowledge**<br>n=21, p=0.12, t=0.38, s=0.62 | Considering domain knowledge (e.g., physics, computing) during interventions or difficulty detection. | "...reassess and make sure that they understand what acceleration is..." |

| | | |
|---|---|---|
| **Feedback Timing**<br>n=20, p=0.11, t=0.6, s=0.4 | When an agent should or should not intervene. | "...wouldn't want to intervene here…" |
| **Personalization**<br>n=16, p=0.09, t=0.38, s=0.63 | Personalizing interventions; student agency in agent interactions; considerations for individuals or dyads. | "...a toggle device would be helpful for those who want to challenge themselves a little more..." |
| **Scaffolding**<br>n=14, p=0.08, t=0.36, s=0.64 | Agent interventions should not give direct answers but instead provide guiding steps. | "...that way, like, the AI isn't giving them, like, the answer to it..." |
| **Strategies**<br>n=12, p=0.07, t=0.58, s=0.42 | Students' problem-solving strategies (e.g., trial-and-error). | "...abandoned the strategy that they were using…" |
| **Social**<br>n=9, p=0.05, t=0.78, s=0.22 | Social interactions/student collaboration as factors guiding agent decisions. | "...I would intervene just depending on, like, how they're getting along..." |
| **Class-Focused**<br>n=7, p=0.04, t=1.00, s=0.00 | Interventions directed at the entire class instead of individuals or dyads. | "...that feels like a thing that the whole class also needs to have reminded of..." |
| **Engagement**<br>n=7, p=0.04, t=1.00, s=0.00 | Student engagement or disengagement as a factor influencing agent decisions. | "...have they, like, thrown up their hands, or they, like, seem like they might start disengaging..." |
| **Task Completion**<br>n=7, p=0.04, t=0.14, s=0.86 | Tailoring interventions to the current task rather than broader learning goals. | "...let them know, like, hey, there's a stop at the beginning of your code..." |
| **Overall Learning**<br>n=5, p=0.03, t=0.80, s=0.20 | Intervention decisions guided by broader learning goals rather than the current task. | "...to actually engage in this sort of learning, and so ensuring that all of that is being met..." |
| **Encouragement**<br>n=4, p=0.02, t=0.00, s=1.00 | Interventions aimed at encouraging or reassuring students. | "…this part of your code looks really good…" |

*n* refers to the number of utterances across all sessions containing each code. *p* indicates each code's relative occurrence as a percentage of all codes. *t* and *s* represent the percentages of utterances for each code from teachers and students, respectively. For example, the *Encouragement* code appears in 4 utterances (n=4), making up 2% of the 176 total codes (p=0.02), all of which come from students (t=0.00; *s*=1.00).

## Design Principles

Figure 3 uses a Venn diagram to visually present each agent's design principles.

**Figure 3**

*Teaching and Peer Agent Design Principles*