Examining How In-The-Moment Interpretations of Student Disciplinary Thinking and Emotions Support Responsive Teaching: A study in AI-Supported Simulation

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Abstract: This mixed-methods study examined an AI-supported virtual simulation and explored the role of preservice teachers' (PSTs) in-the-moment interpretations of virtual students' resources (both epistemic and emotional) in their responsive teaching practices. Thirty-three preservice science and mathematics teachers participated in the study. Linear regression analysis results revealed that PSTs' interpretative acts can significantly predict their responsive teaching practices. Qualitative analysis corroborated that purposive interpretation enabled PSTs to estimate students' learning states and teaching scenarios as a whole. It was also found that PSTs struggled to enact interpretations, pointing to future research directions.

Introduction

Engaging students in inquiry-based discourses is a critical way to promote students' conceptual understanding and reasoning skills in science and mathematics education (Mercer et al., 2004). Teachers' role in supporting such discourses is attending to student resources and facilitating discussions by orchestrating, pressing for, and challenging different ideas (McNeill & Pimentel, 2010). Yet, this responsive way of teaching requires teachers to notice, interpret, and respond to student resources in the moment, being both transformative and challenging (Zhang et al., 2024b). Teachers are expected to but often struggle with recognizing and interpreting various forms of student participation when employing responsive talk moves to promote generative discussion. Expanding teachers' capacity to enact these practices is paramount for preparing a responsive teaching force.

While teachers' noticing and decision-making processes have been actively explored in the literature, the interpretation of student resources received much less attention due to the implicit nature of the cognitive processes. Studies have been inferring teachers' interpretative acts based on how they respond to students rather than observing these acts directly. Moreover, previous research on interpretation has been limited to students' epistemic resources--how well they understand the concepts; the emotional resources that intricately intertwine with learning have been largely unexplored. As such, this study leverages an AI-supported simulation that enables in-the-moment interpretation and reflection to examine how preservice teachers make sense of student resources (i.e., both disciplinary thinking and emotions). Specifically, we are interested in whether preservice teachers engage in interpretative acts and how those acts support their responsive teaching practices.

Responsive teaching in science and mathematics

Recent education reforms in science and mathematics call for more student participation in productive discourse and argumentation (NCTM, 2000; NRC, 2010). Responsive teaching refers to the teaching practices that constantly attend to and build instructions and activities on student thinking (Hammer et al., 2012). When attending to student ideas, teachers take the stance to understand students' in-process thinking rather than evaluate the correctness. Students, correspondingly, assume the role of active participants in the discussion, seeking a critical understanding of the subjects (Engle, 2006). Evidence is accumulating that responsive teaching can foster students' conceptual understanding (Kang et al., 2014) and cultivate equitable and inclusive learning environments (Rosebery et al., 2016).

In-the-moment interpretation of student resources

One important premise of responsive teaching lies in the assumption that students join the classroom with rich resources for disciplinary learning. Teachers should notice, interpret, and respond to these resources in a way that engages students in generative sensemaking and argumentation (Hammer et al., 2012). Responsive teaching requires teachers' in-the-moment interpretation of student resources, including identifying problem-solving strategies, assessing student understandings, and collecting evidence for their interpretations (van Es & Sherin, 2021). Through interpretation, teachers gain an understanding of the substances of student thinking and how to help them connect those resources to the established concepts. Prior research has shown that these moments of sensemaking of students' thinking or learning states enable and support teachers' adoption of responsive teaching practices (Dyer & Sherin, 2016). However, due to limited research, little is known about how teachers conduct in-the-moment interpretation.

Another important student resource that receives undue attention is student emotions. Emotions are natural results of interactions with objects, people, and environments, thus ubiquitous in educational settings and affecting how students learn (Pekrun & Linnenbrink-Garcia, 2012). A responsive classroom fosters a socially, emotionally, and intellectually safe environment where students' diverse emotions are validated and attended to, and where students feel safe to tackle cognitive risks (Hammond, 2014). Positive emotions are the foundation of students' cognitive and motivational engagement in learning and have been shown to be associated with academic achievement (Pekrun & Linnenbrink-Garcia, 2012; Valiente et al., 2012). As such, when interpreting student resources to inform teaching decisions, it is not enough to focus solely on their disciplinary thinking; students' emotions must also be acknowledged and validated.

AI-supported teaching simulations

The call (Grossman et al., 2009) for making practice a central component of teacher education has brought increasing attention to teaching simulations (Ke et al., 2020). Preservice teachers, who receive predominantly conceptual training, can practice fundamental teaching skills in teaching simulations and gain fluency and preparedness in teaching (Lee et al., 2023; Sebastian & Krishnamachari, 2023). Teaching simulations can be designed to simulate different teaching scenarios for diverse teaching skills, ranging from discourse skills (Barrett et al., 2025) to inclusive practices (Rayner & Fluck, 2014). As such, teaching simulations can be a promising tool to bridge the theory and practice of teaching.

Despite the promises, a salient challenge of using traditional teaching simulations is the lack of reciprocal teacher-student interaction within these environments. The simulated classrooms are usually equipped with virtual students which are role-played by peer teachers or human actors. Participating teachers perceived the interaction as unauthentic compared to teaching real students (Dalinger et al., 2020). They also express fear and pressure of peers' presence, which might affect their performances in the simulation (Dalinger et al., 2020). In some other simulations, virtual students are scripted to generate limited discourse. Teachers reported that students' responses are unpredictable (Rayner & Fluck, 2014), and there is a lack of reciprocity in their interaction (Ke et al., 2020).

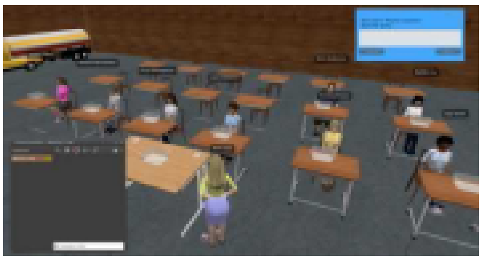
Recently, the development of AI technologies, specifically large language models (LLMs), has given rise to AI-powered virtual students that can be integrated into teaching simulations (Zhang et al., 2024a). AI powered virtual students, powered by LLMs, can generate naturalistic and authentic discourse similar to those in real classrooms (Zhang et al., 2024b). The increased realism and interactivity in AI-powered virtual students facilitate preservice teachers' engagement in pedagogical reasoning and teaching practices (Dai et al., 2024; Zhang et al., 2024b).

Method

AI-supported teaching simulation

This mixed-methods study employed *EVETeach* (Enactive Virtual Environment for Teaching Practice), a virtual teaching simulation designed to prepare science and mathematics teachers for adaptive and effective teaching practices. Designed in the open-source, desktop virtual reality platform, *OpenSimulator*, the simulation featured a STEM classroom, populated with eight AI-powered virtual students (Figure 1).

Figure 1
The EVETeach Simulation



*Evely*n (student agent model) is powered by the LLM, Generative Pre-trained Transformer 3.5. Evelyn was first trained with human-labeled transcripts from 569-minute real classroom videos (TMISS and Ambitious Science Teaching), then fine-tuned with prompt engineering to generate responses with low, medium and high levels of understanding (Bhowmik et al., 2024).

Participants, data collection and analysis

This study involved 33 preservice teachers (all female) recruited from several research universities in the US. Participants' focus of study consisted of science (n = 21) and math (n = 12). Seventy-four percent of participants were undergraduate and 26% were graduate students.

Participants had individual, 2-hour online sessions with one human facilitator in the virtual simulation. They completed a brief training module and taught a lesson to the virtual students on a specific math or science topic. Participants were encouraged to talk-aloud their thinking processes, while the facilitator might occasionally prompt teachers to share their thoughts. At the end of the session, participants completed a semi-structured interview and a responsive teaching knowledge test. All sessions were recorded and transcribed verbatim.

This study employed both quantitative and qualitative analysis to render a comprehensive picture of PSTs' in-the-moment interpretative acts. For the quantitative component, a linear regression analysis was conducted to predict PSTs' responsive teaching practices (dialogue transcripts coded with responsive teaching talk moves, Zhang et al., 2024b) by their interpretative acts (coded into epistemic and emotional interpretation). All the variables were standardized on the same scale to be comparable. The qualitative component triangulated data from video recordings, interviews, and dialogue transcripts to illustrate the role of teacher interpretation in their responsive teaching practices. Pseudonyms are used throughout.

Results

Regression analysis

The results of the descriptive analysis (Table 1) showed that PSTs make more inferences about student understanding and validate student emotions than interpreting the emotional qualities or reflecting on the impact of their teaching decisions on student emotions. A great variability was observed in the synthesis of student ideas and emotional validation, indicating potentially distinct interpretative patterns.

Table 1
Descriptive Statistics of PST Interpretative Acts

Category	Interpretative acts	Mean (SD)	Min	Max
Epistemic	Assess prior knowledge	2.33 (2.61)	0	10
	Synthesize different ideas	7.55 (21.09)	0	88
	Make inferences about student understanding	9.33 (5.30)	3	22
	Connect everyday with disciplinary concepts	2.94 (4.23)	0	17
	Reflect on the impact of pedagogy on learning	7.58 (8.08)	0	28
Emotional	Interpret emotional qualities	1.73 (3.59)	0	14
	Emotional validation and empathy	9.85 (12.75)	0	57
	Reflect on the impact of pedagogy on emotion	1.03 (1.33)	0	4

A simple multiple linear regression was conducted (Table 2). It was revealed that PSTs' interpretative acts can significantly predict how they teach in the virtual classroom ($F_{(2,30)} = 129.78$, $p < .001$). Specifically, epistemic interpretation can significantly predict productive responsive teaching practices. This indicated that for every unit of increase in epistemic interpretation, teachers' responsive teaching moves will increase around .81. PSTs, emotional interpretation is a significant predictor only when it is the sole predictor in the model. However, it was not a significant predictor when holding epistemic interpretation constant. These results could be due to the high correlation between the two variables ($r = .92$).

Table 2
Linear Regression Analysis

	Standardized β	SE	*p*
Epistemic interpretation	.808	.150	< .001
Emotional interpretation	.149	.334	.323

Qualitative analysis

PSTs' interpretative acts support responsive teaching practices

The AI-supported simulation enabled ample space for interpretation and reflection, which would likely be perceived as infelicitous or disturbing for real students. Teachers reported that they did not feel pressured to respond to students immediately as in real teaching. Meanwhile, teachers shared that they viewed AI-powered virtual students as similar to real students and were observed to invest in interpreting and understanding student resources. As Emily shared in the interview, "I feel like, what motivates me is the way how they're able to relate

or respond to what I'm like teaching. It kind of feels like it's like a real person asking me questions or giving me an example. So it's really interesting to see how I can interact with them."

Engaging in interpretations of student resources helped teachers make sense of students' understanding or learning states in relation to the overall, context-rich teaching scenario. Based on these understandings, they could implement more targeted and responsive teaching moves. Consider the following example in Gloria's gas law class,

John (S): What did the steam do to the outside of the container?

Gloria (T): (Thinking aloud) Okay, he probably thinks that this steam caused it to crash from the outside rather than being sucked in. Things like there was just pressure coming in instead of it just being pulled. Maybe I can ask him … (turning to John) Did the tank get crushed from the outside or collapse from the inside?

John (S): I think it got crushed.

In this scenario, John was confused about the role of steam in the tank car implosion. Gloria captured the keywords 'steam' and 'outside' in John's question and interpreted it as relating to the direction of force. She thus asked a follow-up question to prompt John to share his theory. This interpretation resulted in an interactive conversation that led to the discussion of pressure difference and how it is formed.

On the other hand, PSTs' emotional interpretations can lead to either productive or unproductive decision making. For example, Bella decided to talk to the whole class after interacting with specific students, reflecting, "I don't want another group to feel left out." Such interpretations and decisions prompted responsive and equitable instruction. In other cases, PSTs' emotional validation was limited to being courteous by acknowledging students' responses, which did not improve their responsiveness. As an example, when a student said she was unsure how fungi reproduce, she playfully remarked, "Maybe it depends on its mood or something." Susan responded, "This is an interesting thought, but let me tell you that fungi reproduce asexually."

Challenges in enacting in-the-moment interpretation

One challenge observed is that some PSTs were not comfortable with making interpretations. Making sense of student resources was not part of their teaching routine, so many did not know what or how to interpret. Bella, for example, indicated that, when being prompted to share her ideas on classroom discussion, "I think that I am struggling to understand Linda. What I'll probably do is [to say], to the whole class, turn and talk to your partner." PSTs also mentioned that it could be because of their lack of content knowledge, which could not support such interpretation and synthesis.

Another challenge PSTs mentioned is that they could not identify virtual students' emotions as there were limited cues. As Julie expressed, "It looks like every student is just sitting there attentive and listening and waiting to answer your question." Similarly, Jody reflected in the interview that it was harder to interpret emotions in the simulation compared to real classrooms, "In the [real] classroom, I can read the emotion of the class from other members of the class as well. [But] if it was like in an online situation like this, the emotions have to be very extreme."

Discussion

The study aimed to understand the role of teachers' interpretation of student epistemic and emotional resources in their teaching and how AI-supported simulation mediated the process. Linear regression analysis revealed that PSTs' in-the-moment interpretations of student resources can significantly predict their responsive teaching practices, which affirms the findings of a previous study (Dyer & Sherin, 2016). Specifically, PSTs' emotional interpretation is a significant predictor only when it is the sole predictor of responsive teaching practices. This means that it shares variance with epistemic interpretation, but its unique contribution to responsive teaching is small when epistemic interpretation is considered. Qualitative analysis revealed corroborating evidence that AI based simulation offered a low-stake environment for interpretation and reflection, which facilitated responsive teaching. In-the-moment interpretation supported PSTs to identify students' learning states and take the overall teaching scenarios into account, which assisted them in making responsive and equitable instructional decisions. However, PSTs also struggled with interpretations due to the lack of interpretation awareness and content knowledge, as well as limited contextual cues in the simulation. This finding aligns with that of a previous study (Dai et al., 2024; Zhang et al., 2024b) which suggested that in-situ support is needed to maximize learning outcomes. It also sheds light on future AI-powered virtual student designs, indicating that cognitive-affective states should be integrated into virtual student modeling to enhance authenticity and interactivity (Bhowmik et al., 2024).

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