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The Role of Teacher Framing in Shaping Student Agency in Human-AI Partnered Science Classrooms

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Abstract: This study is part of a larger research project aimed at developing and implementing an NLP-enabled AI feedback tool called PyrEval to support middle school students' science explanation writing. We explored how human-AI integrated classrooms can invite students to harness AI tools while still being agentic learners. Building on theory of new materialism with posthumanist perspectives, we examined teacher framing to see how the nature of PyrEval was communicated, thereby orienting students to partner with or rely on PyrEval. We analyzed one teacher's talk in multiple classrooms as well as that of students in small groups. We found student agency was fostered through teacher framing of (a) PyrEval as a non-neutral actor and a co-investigator and (b) students' participation as an author and their understanding of the nature of PyrEval as core task and purpose. Findings and implications are discussed.

Introduction

This study responds to emergent inquiries around how human-AI partnered classrooms can be designed to cultivate students' ability to harness AI tools while also directing their own learning. Worries about AI dominance have been around for decades in fiction worlds but are more real now in nonfiction worlds. With increasing use of AI in education, researchers and practitioners are concerned about learner agency in AI-integrated classrooms. Recent research describes compromised agency of students with heavy reliance on AI (e.g., Darvishi et al., 2024). We thus question what measures are needed for students to work with AI as tools and materials to support their own learning, rather than as epistemic authority to do the work.

Our focus is on the role of teachers in shaping student agency in AI-integrated classrooms. We are specifically interested in how teachers frame AI and student tasks in AI-integrated science classrooms. Teacher framing refers to use of meta-communicative signals to help students make sense of and interpret activities in which students participate (Engle, 2006; Harris et al., 2020; Kawasaki & Sandoval, 2019). We attend to teacher framing that not only shapes student agency but also orients students to perceive the nature of AI. Drawing on new materialism and posthumanism (Peppler & Thompson, 2024; Tang & Cooper, 2024), we see AI as actors that are "beyond materials simply as mediators of activity" (Peppler & Thompson, 2024, p. 4). While this view is aligned with that of Puntambekar et al. (2024) in which AI plays the role of a partner with teachers and students in science classrooms, we examine *teacher framing* in the present study that may serve to enable (or disable) such partnership. Specifically, we are interested in *how the nature of AI may have been communicated in teacher framing*, thereby orienting students to partner with or rely on AI (or in between on the spectrum). This examination is important because the *nature* of tools and materials inter-act and intra-act with students (Barad, 2003; Peppler & Thompson, 2024; Tang & Cooper, 2024). In the present study, *nature* does not mean "prescriptive essentialism" of tools and materials (Barad, 2003, p. 828). Rather, it means *coded nature* that emerges through inter-action and intra-action with users. While the meaning of nature in the present study is the same as that of identity of tools and materials in Peppler and Thompson (2024), we chose to use nature to avoid a possibility of confusion from the term, identity, that may suggest referring to self-development of identity *within* AI. Identity of circuitry toolkits without AI integration was examined in Peppler and Thompson (2024).

Research questions

Our overall inquiry was to explore if and how human-AI integrated classrooms invited students to harness AI tools while still being agentic learners. Ultimately, we are interested in how human-AI partnered classrooms can be designed to help students see themselves as agents with voice and choices. Our research questions were:

1. What meta-communicative signals does the teacher use to frame the nature of AI and students' engagement with AI, and why?
2. How does the framed nature of AI relate to students' sensemaking of AI and agency in their activities?

Theoretical framework

The present study builds on theory of new materialism with posthumanist perspectives (Barad, 2003; Gamble et al., 2019; Peppler et al., 2020; Peppler & Thompson, 2024) to explore the nature of AI and its role especially in student agency in science classrooms. New materialism is an interdisciplinary theory and movement that challenges (a) dualism separating between humans and non-humans, and (b) humancentric orientations viewing non-humans as passive and neutral (Barad, 2003; Gamble et al., 2019; Peppler & Thompson, 2024; Tang & Cooper, 2024). New materialism began as a response to technological changes as well as ecological crisis. New materialism emphasizes interconnectedness between humans and material things in which neither entity is predetermined but one responds to and shapes the other and vice versa (Peppler et al., 2020; Peppler & Thompson, 2024). Discursive practices between human and materials create ongoing co-created meaning (Barad, 2003).

In essence, new materialism decenters humans as in posthumanism that refutes the assumptions of humans being superior to and autonomous from non-humans (including nonliving matter). Within new materialism, "notions of agency (i.e., the ability to act) can be seen as not resting solely with humans" (Peppler et al., 2020, p. 1240). Materials have histories and agency with which humans work together through intra-actions (Barad, 2003; Peppler & Thompson, 2024). According to Barad (2003), "*intra-action* (in contrast to the usual "interaction," which presumes the prior existence of independent entities/relata) represents a profound conceptual shift" (p. 815). For example, Peppler & Thompson (2024) argued that when such tools as e-textiles are communicated about their nature of gendered qualities, they can impact learning by inter-acting and intra-acting with students. We view humans as neither superior to nor autonomous from AI used in the present study. We hypothesized that the nature of AI that is communicated through inter-action and intra-action with teachers and students foster or hamper student agency in AI-integrated classrooms.

Seeing tools and materials as entities that have agency (Peppler et al., 2020; Peppler & Thompson, 2024; Tang & Cooper, 2024) is important in AI-integrated classrooms, especially considering materiality of AI that contains components of human agency such as learning and decision making. Also given discussions of shared agency in AI-powered contexts (e.g., Godwin-Jones, 2024), knowledge of how to still cultivate student agency in AI-integrated classrooms is needed (while still steering away from anthropocentric orientations).

For such knowledge building, we ground the present study also in teacher framing research (e.g., Engle, 2006; Harris et al., 2020). Framing is about "how we use speech to organize and interpret an understanding of social interaction" (Kawasaki & Sandoval, 2019, p. 909). Teacher framing in the present study is considered a window into how intra-action may have been guided between students and AI. For example, teacher framing of activities involving AI could guide student perceptions about AI and agency; if teachers frame science writing revisions as activities of adding science concepts that AI indicates is missing in student writing, students could perceive AI as a tireless, consistent machine that always provides useful information, which in turn could hamper student agency. Research has shown the important role of teacher framing in learner agency (e.g., Engle, 2006; Harris et al., 2020; Kawasaki & Sandoval, 2019).

Method

Study context and participants

As a part of a larger research project aimed at developing and implementing an NLP-enabled AI feedback tool called PyrEval to support students' science explanation writing, one hundred 8th-grade students from one science teacher's classes in the midwestern U.S. participated in the present study. Students were provided with a design challenge to design a roller coaster that was fun and safe based on physics. To learn about the science needed to explain their ideas in their design essays, students generated questions, conducted background research using the project's digital notebook, and performed three simulated experiments to learn about how height and mass impact the amount of energy as well as about the law of conservation of energy and energy transformations. Then, students wrote their initial design essays and submitted them to get feedback from PyrEval within the digital notebook. Before receiving AI feedback, students engaged in peer review activities using historic sample essays to help them learn to use AI feedback in their revisions. Students then revised their own essays using AI feedback and resubmitted for another round of AI feedback for further reflection.

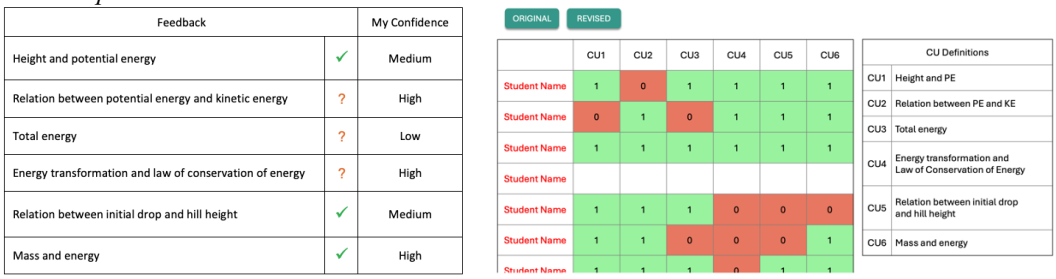
Our NLP-enabled AI tool: PyrEval

PyrEval identifies weighted vectors of key content ideas and relationships, called content units (CUs), from a small sample of reference, or wise-crowd responses (Singh et al., 2022). We created a specific main idea rubric by identifying key science ideas from both prior middle school students' roller coaster design essays as well as different target ideas that students were expected to learn during the unit and include in their essays. In the end,

we identified six highly weighted CUs that students were expected to include in their design essays: 1) a higher initial drop means greater potential energy, 2) there is an inverse relationship between potential and kinetic energy as the car moves up and down the track, 3) without friction, the total energy in a roller coaster system is the potential plus kinetic energies of the car at any point on the track, 4) the law of conservation of energy, 5) to have enough energy to finish the ride, the initial drop height must be higher than subsequent hills, and 6) a roller coaster car with greater mass will have more energy for the ride.

Once an essay is submitted to the digital notebook, PyrEval parses it into propositions, identifies whether each CU is present or absent, and produces a vector score; a 1 indicates that PyrEval detected a particular CU in an essay. In the example in Figure 1 (left), PyrEval detected CUs 1, 5, and 6 in a student's essay. Vector scores for researchers are recorded as follows: [1,0,0,0,1,1]. Through co-design with participating teachers and prior implementations, PyrEval feedback was presented in a table format to make feedback easier for students to understand. The feedback table also included AI accuracy information (called my confidence) based on a training set of essays to help students to better target where to start their revisions. For example, if PyrEval did not detect a CU in an essay and the accuracy was high, it is very likely the student did not include the science ideas in that CU, or did not explain them clearly. As shown in Figure 1 (right), PyrEval also produced aggregated summaries of the CUs students included in their essays at a class level for teachers to see the CUs students may be struggling to write about so they could provide targeted support.

Figure 1.
Sample AI Feedback to Students and Teachers



Data analysis

We analyzed one teacher's talk and associated actions during her whole class teaching as well as her interactions with small groups to examine her framing of the nature of PyrEval and students' engagement with PyrEval. We also analyzed students' talk and actions in small groups to examine their sensemaking of PyrEval and agency.

We reviewed a larger set of videos multiple times and then analyzed five videos (see Table 1) recorded during the period between initial design essay submissions and revision submissions. These videos focused less on science concept teaching and more on using AI in science explanation revisions, which contained rich data for analysis to address our research questions. Teacher videos were selected from two classes teaching different sets of students. Videos were transcribed using Adobe Premiere Pro 25.0, and then manually revised by one researcher multiple times and double-checked by another researcher. Some gestures (e.g., nodding) were also transcribed when important to the communication within the scene. We then coded video transcripts using our coding scheme.

Table 1.
Information about the Videos Analyzed in the Present Study

Videos	Focus of recording	Class topic	Class section and group	Duration (m:s)
1	Teacher whole-class recording	Peer review	Class section 6	33:35
2	Teacher whole-class recording	Essay revision	Class section 6	37:00
3	Student group recording	Peer review	Class section 7 Group 2	19:12
4	Student group recording	Essay revision	Class section 7 Group 2	42:43
5	Student group recording	Essay revision	Class section 7 Group 3	42:19

A coding scheme was constructed based on new materialism with posthumanist perspectives (Barad, 2003; Gamble et al., 2019; Peppler et al., 2020; Peppler & Thompson, 2024) and teacher framing (Berland & Hammer, 2012; Engle, 2006; Harris et al., 2020; Kawasaki & Sandoval, 2019). A total of 33 subnodes were generated under the five parent nodes: teacher framing of students and their activities, teacher framing of tools and materials, materiality and nature of PyrEval, teacher framing types, and student perception and comments.

We analyzed the data based on the coding scheme using NVivo 14. Two researchers went through pilot coding and discussion to review discrepancies and reach consensus. The coding scheme was then revised. One researcher re-coded the pilot-coded data and the remaining data using the revised coding scheme, and the other researcher reviewed all coded data. They reviewed discrepancies and reached consensus. They discussed salient observations (compiled in a single-spaced 62-page document) in multiple meetings as part of meta-sensemaking of the coded data. They generated a list of themes from meta-sensemaking and finalized the list with another researcher. The coding scheme example nodes and relevant data are listed in Table 2.

Table 2.
Teacher Framing Code Examples and Coded Data

Teacher framing of …	Data example
The nature of student engagement with PyrEval	"I have a suspicion that student B got their feedback, looked at it, and then just added more sentences to their writing. Right?"
The materiality of PyrEval	"Edit in your current essay and then submit it again. You'll then see your revised essay which will be processing. Then they get processed after 3 o'clock today."
The nature of PyrEval	"I've noticed PyrEval really struggles with mass. I can't really explain why."
The role of students as an author	"(…) the students didn't really edit. They just added it and it ended up being repetitive and it ended up being more confusing. (…) So the big idea here is that we're working on making what we have better."
The role of students as a recipient of others' knowledge	"So one thing you want to do is to make sure that you've clearly shown that, you know, that this is a law, the law of conservation of energy."
The role of PyrEval as a co-investigator	"So even if you get the green check marks, it would be beneficial to still check your essay to see how you can improve it."

Findings and discussion

Five themes emerged from meta-sensemaking of the coded data. We discuss them in relation to research questions.

RQ1 on teacher framing of the nature of AI and student engagement with AI

Theme 1. The teacher framed AI as a non-neutral actor

The teacher's meta-communicative signals were rarely about the material components of PyrEval. Her talk and actions were about the nature (i.e., identity in Peppler and Thomson (2024)) of PyrEval. That is, she often used human-like descriptions about PyrEval instead of framing it as a fast machine always with consistent information. For example, she stated, "I've noticed PyrEval really *struggles* [emphasis added] with mass. I can't really explain why". Considering some optimism about AI in general that stemmed from its materiality of quick and consistent performance of a large amount of work (e.g., Qin et al., 2020), the teacher's framing of PyrEval as a non-neutral actor is unique and important. If she had framed PyrEval as a neutral machine, this would likely have ultimately impeded her agency as a teacher but also that of her students by taking over the classroom space, as Peppler and Thomson (2024) argue, "[w]hen a tool, environment, or experience is coded as "neutral," it creates space for those with power to fill and overtake" (p. 26).

The teacher's meta-communicative signals were also not just about the nature of PyrEval that she had known about from her two rounds of implementations in the previous years. That is, the nature of PyrEval was not predetermined. For example, when showing her summary of aggregated reports from PyrEval to class, she pointed out newness that she was experiencing with PyrEval during this third round of implementation.

> Like a lot of question marks, right? Over a half had question marks for these two topics. *Something that I found interesting that I can't really explain yet* [emphasis added]. Well, I edited this slide [showing her summary of aggregated reports from PyrEval] from last year, so I was looking at last year's results that I shared, and this topic [law of conservation of energy] was actually listed as a best topic. So, *it's kind of interesting how it kind of changed [to be on] the other side of the table this year* [emphasis added].

In this example, the teacher was not just talking about students' writing and lack of their explanation of law of conversation of energy. She was also talking about the nature of PyrEval that detected the content unit (CU4: the law of conversation of energy; see Figure 1) less than previous implementations. When working with past implementations, she had known that PyrEval was quite good at detecting CU4. She attempted to understand the nature of PyrEval at the moment as she worked with it, and also framed the tool for her students as she experienced, not in a predetermined way. Also considering (a) the inevitable impact of writing quality on PyrEval's reaction,

and (b) the fact that CU4 was one of the best detected explanations after students' revisions that occurred after the time of this teacher talk (i.e., students improved their writing about CU4 and PyrEval detected it better than their first version of explanations), the newness that the teacher referred to above is an example of co-created meaning from discursive practices between humans and nonhuman materials as Barad (2003) described. None of the entities (the teacher, students, and PyrEval) was predetermined, and they responded to one another and were shaped as they inter-acted and intra-acted with one another (Barad, 2003; Peppler & Thompson, 2024).

The teacher's intra-action with PyrEval is corroborated by her discourse also about her sensemaking in progress about PyrEval. For example, when communicating about how and why PyrEval gave feedback the way it did, she often noted that her account was less than perfect. For example, when talking about PyrEval's feedback on one of the sample essays, she said, "I'm not 100% sure, but this is my guess". From posthumanist perspectives, this kind of teacher framing allows tools and materials "as an active participant in the world's becoming, in its ongoing "intra-activity"" (Barad, 2003, p. 803).

Theme 2. The teacher framed AI as a co-investigator

The teacher's meta-communicative signals framed PyrEval as a co-investigator. As shown in Table 2, the coding scheme included nodes for positional framing. Positional framing refers to how the roles of participants are conceptualized and expected in the classroom (Greeno, 2009; Harris, 2017). The importance of positional framing in learner agency, knowledge building, and transfer has been studied (Berland & Hammer, 2012; Engle, 2006; Greeno, 2009; Harris, 2017). We examined teacher talk and actions to see if the role of PyrEval was framed as an epistemic authority, an information provider, and/or a co-investigator.

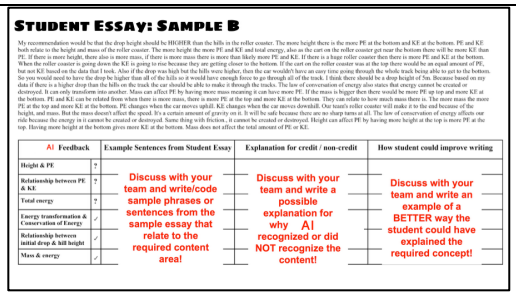
While PyrEval was an information provider in a sense that its feedback presented a list of check marks and question marks to each student, its role as per teacher framing was that of a co-investigator because she frequently asked students to use the feedback information to investigate which parts of design essays need to be improved and in what ways. For example, the teacher stated in the essay revision class:

> You're going to take a look at your feedback, right? Take a look at where you got question marks first. It's not that you don't look at your check marks, but these two would be the categories I would start revising in my essay and then moving on to check the others.

As shown above, students were tasked to investigate their essays first with question marks and continue with checkmarks that PyrEval had given after its investigation through automated assessment. Such teacher framing of PyrEval as a co-investigator was observed also during peer review classes in which students investigated why PyrEval detected or did not detect certain content units (as results of its investigation) in each of three sample essays (Table 3). Even though PyrEval was not there to speak with students during the investigation process, pluralistic meanings of check marks and question marks at the moment of peer reviews that they had to discuss with their group members made PyrEval neither static nor passive.

Table 3.

Example of Teacher Talk in Class 6 about Feedback from PyrEval

No.	Excerpt
	 *(The teacher pointed at various places on the screen showing this essay sample containing AI feedback)*

1 So this green checkmark here does not guarantee that it is correct.
2 And, in there.
3 In fact, I have been informed after many years of using PyrEval now that PyrEval gives more false positives than it does false negatives.
4 So, in other words, when there's a question mark, it's usually right that you didn't cover it or it wasn't clear.
5 Right. But when there's a checkmark, there's a decent number of times that it is wrong.
6 That it's not actually covered clearly, maybe it's there, but it's maybe, like here, it's incorrect.
7 The whole concept [written in the essay] is wrong. *(pointing at the top portion of the sample essay)*
8 It contradicts itself. *(pointing at the top and bottom portions of the sample essay back and forth)* Right?

9 So even if you get the green check marks, it would be beneficial to still check your essay to see how you can improve it.

The role of PyrEval that the teacher framed was that of a co-investigator also because her meta-communicative signals were far from orienting students to see PyrEval as a knowledge authority. As shown in Line 9 above, the teacher guided students to still investigate in what ways the parts of the sample essay that received check marks from PyrEval could be improved.

Teacher framing of PyrEval in the present study as a co-investigator is pedagogically instrumental in that student agency can be still fostered as students are also framed as investigators who partner with AI. But this finding is also meaningful within the theory of new materialism because it showcases that AI tools and materials can be perceived as non-neutral through experiences that the teacher frames for students. As Peppler and Thompson (2024) noted, the nature of tools and materials are perceived "based on practices and experiences associated with the materials rather than solely based on the appearance of the [circuitry] kit" (p. 27).

Theme 3. When students engaging with AI, teacher talk framed student participation as an author

The teacher's meta-communicative signals framed student participation as authors when engaged with AI. As shown in Table 2, the coding scheme included nodes for *participation framing* as an author or a recipient of others' knowledge (Engle, 2006). While our research inquiries in the present study are not specifically related to transfer of science explanation writing, our hope was to find methods of impacting learner agency in AI-integrated science learning classrooms. We thus examined teacher framing of student participation that is related to student empowerment as noted in Engle (2006):

> Being framed as an author—rather than simply as a recipient of others' knowledge—creates social expectations that one will be able to comment intelligently on anything related to the content that one has authored, making one answerable for that content in the future. (p. 457)

We found that the teacher constantly guided students to be an author when engaged with AI. She framed that methods of improving science explanations should be, in the end, theirs. For example, in the peer review class, she highlighted that the fact that PyrEval says CU1 is missing should not lead to using the method of simply adding one or more sentences about CU1:

> My gut feeling is that the students didn't really *edit*. They just *added* it and it ended up being repetitive and it ended up being more confusing. Right? So the big idea here is that we're working on making what we have better.

In the essay revision class, the teacher exhibited her expectation for students as authors who develop methods of improving their own essays through editing them, not by adding things that were absent only according to PyrEval.

> Today I really want you to focus on revising, not just adding more stuff. So, for example, with Student B [a deidentified writer of Essay Sample B], I have a suspicion that Student B got their feedback [from PyrEval], looked at it, and then just added more sentences to their writing. Right? [As for] Student B, I heard a lot of people [in the peer review class] saying, they already said this four times.

Not only PyrEval 's question marks but also check marks were framed to guide student participation as an author:

> Here's one example right here. Right. This person needs to improve what they have for mass. They have to, right? So if they just ignored mass because of this green check mark, they'd have some incorrect content in here. Right?

The teacher talk above is grounded in her intra-action with PyrEval as discussed earlier. PyrEval formed part of the interconnectedness between humans and nonhumans, rather than a tool "simply as mediators of activity" (Peppler & Thompson, 2024, p. 4). The interconnectedness enabled the teacher to frame PyrEval as an author of feedback but also students as authors of methods for improving their own explanation writing.

Theme 4. Teachers framed understanding of how AI works as part of student task and purpose

The teacher framed that students were tasked to understand how PyrEval works. Not only in the peer review class but also in the essay revision class, the teacher made such understanding as core. While each class activity had its own main task and purpose – one reviewing sample essays to learn how to use the feedback in revisions and the other revising own essays to improve essays, the teacher framed both activities for students to learn to understand PyrEval. For example, the teacher introduced her slide listing topics that students explained better than other topics in their essays and needed to improve (Table 4). But this was one of the methods that she used to guide students to think behind the scenes (listing PyrEval feedback) to understand why PyrEval struggled and when it did and why PyrEval did not struggle and when it did not; that is, fundamentally about how PyrEval works, but not necessarily about material components of PyrEval (such as NLP) but about the nature of PyrEval such as its

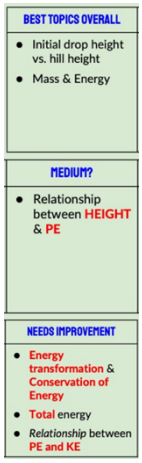
struggle with redundant explanations. In this example, the teacher told the class which CUs did not receive check marks as many as other CUs, but to facilitate students' experience with the nature of PyrEval.

As evidenced in the teacher framing literature (e.g., Harris et al., 2020), framing of student task and purpose contributes to student agency. Framing of student task and purpose may be even more important in the present study because students engage with not only AI that contains characteristics of human agency but also epistemology that involves AI, both of which could shape learner agency. The teacher's intra-action with PyrEval but also her framing of students' intra-action with PyrEval to understand its nature that are co-created seems to have made the role of PyrEval beyond just that of a mediator without hindering student agency.

Table 4.

Example Teacher Talk about Aggregated PyrEval Feedback

No.	Excerpt
1	So, the best topic overall meaning the most green checkmarks was this idea about the initial drop height versus the hill height. Alright.
	(…)
2	Kind of the medium one. Right.
3	It was this relationship between height and PE [potential energy] and this is one that I think that is probably addressed in most, if not all, essays.
4	I don't think it's a lack of including it.
5	I think this is more about a clarity. Right.
6	Because the relationship is pretty simple. If you have more height, PE [potential energy] will be? [The class responded by saying "higher"]
7	Higher. So, great, here, that's the relationship. Alright.
8	I feel like perhaps it maybe got hidden in too long of a sentence or muddled in with something else. Right?
9	So just making sure that that relationship is a little more clear.
10	Alright. The needs improvement list, something that I found interesting.
11	These [first] two topics here are in every single class's spreadsheet. Everyone['s].
12	So, all five of my classes has these [first] two as their one that had the most question marks.



RQ2 on the relation of teacher framing to student sensemaking of AI and agency

Theme 5. Students did not see AI as epistemic authority

The teacher framed PyrEval as a partner with whom she can disagree. For example, as shown in Lines 11 through 13 in Table 5, the teacher described PyrEval's assessment of Essay Sample C, but she added that she would replace the four check marks that PyrEval gave with question marks. As depicted in the conversations between students and the teacher in Table 5, the teacher's disagreement with PyrEval was based off of her agreement with students' noticing of repetitiveness and lack of quality in the essay sample. Thus, not only her framing of PyrEval as a partner whose knowledge is not always the source for others to rely on, but also her framing of students as a co-investigator whose knowledge can be the source for others to trust seem to have guided students' sensemaking of AI that intra-acts with their agency.

Table 5.

Example Teacher Talk with Student Group 2 in the Peer Review Class

Sub.	No.	Excerpt
S1	1	They just stated everything right at the start
S4	2	And then they go to a detail later and just kind of not me
S1	3	Fully describe it later.
S2	4	(laughter) The entire las[t] the last part
T	5	It's quite repetitive. Yeah, lots of students are noticing that. They're like.
S2	6	Oh.
T	7	They said it. And now they said it again. But they said it slightly different.
S1	8	Then they're saying *that* a little bit different.
T	9	Yeah.
S3	10	Wait, are there any like really good?
T	11	I mean [Essay Sample] C has four checkmarks. So that's the one that has like, according to PyrEval, will be the best [among three sample essays].
S4	12	Yeah.

T	13	But I didn't include any [of] six check marks.
S2	14	I feel they should be also graded on their like grammar because there are like fifty different grammar mistakes.
T	15	There are. It would be interesting if they could recognize more if they just fixed grammar. Like that one.
S2	16	Oh. There is a comma right after a period.

Students indeed freely disagreed with PyrEval as shown in the small group discussion below from Student Group 2 during the essay revision class.

S2: But Essay B is horrendous.

S1: Yeah, I feel like I'd rather read Essay A than Essay B even though they [Essay Sample B writer] checked out four [actually three] marks in Essay B, I feel like.

Students were empowered to even imagine that PyrEval was entirely wrong. In the essay revision class, when hearing the teacher saying, "I learned that PyrEval is [gives] more false positives than false negatives", one student in Group 3 told a classmate at his neighboring group table, "Imagine the check marks you got were actually all supposed to be question marks". Such imagination is playful and yet crucial to learner agency. In the present study, teacher framing enabled students to still exercise epistemic agency in revising their science explanations. As evidenced in much literature (e.g., Kawasaki & Sandoval, 2019), the locus of epistemic agency is important in student science learning.

Despite the potential problems induced by over-reliance on AI such as diminished analytical thinking and critical thinking in recent research (e.g., Zhai et al., 2024), Group 3 students in the present study demonstrated their analytical, critical thinking as follows:

S3: He didn't use evidence.

S2: Yeah.

S1: I mean, this guy did.

S2: Or he didn't explain it all 'cause some didn't make sense on the ones that we did at least.

S3: Yeah

S1: They reused a bunch of sentences like

S2: Yeah

S1: Didn't make like a lot of sense

S3: Yeah

We do not attribute disagreement with PyrEval in these examples to humancentric orientations in which humans see themselves superior to and autonomous from tools and materials. Rather, our attribution is to the nature of PyrEval that the teacher and students intra-acted with. As shown in data excerpts so far, the teacher did not orient students to become independent from PyrEval's feedback. Instead, her framing guided them to attempt to understand and work with PyrEval. This seemed to have facilitated interconnectedness between humans and non-humans highlighted in the theory of new materialism (Peppler et al., 2020; Peppler & Thompson, 2024).

Implications

Our study findings contribute to the knowledge of how human-AI integrated classrooms can be designed to still cultivate agentic learners, especially through a posthumanist lens of new materialism. Agentic learners are those who are empowered to direct their learning. We found student agency was fostered in the present study through teacher framing grounded in interconnectedness between humans and nonhumans (Barad, 2003; Gamble et al., 2019; Peppler et al., 2020; Peppler & Thompson, 2024). We attribute observed student agency to teacher framing of (a) PyrEval as a non-neutral actor and a co-investigator and (b) students' participation as an author and their understanding of the nature of PyrEval as core task and purpose. Specifically, the teacher used human-like descriptions about the nature of PyrEval (who can struggle, for example). The teacher's talk and actions were not based on histories of PyrEval but through intra-action with it. She shared newness that emerged from her intra-action with PyrEval with students whom she also guided to intra-act with PyrEval. The teacher framed PyrEval and students as co-investigators. We found no meta-communicative signals that oriented students to perceive PyrEval as an epistemic authority. The teacher's talk and actions were to cultivate students as authors of developing methods and knowledge of improving their science explanations while still connected with PyrEval and harnessing its feedback. Students did not hesitate to disagree with PyrEval. Their empowerment to be critical with PyrEval was not from humancentric orientations given that they were becoming critical also with others' writing as well as that of their own. Teacher framing that allowed student agency in the present study is meaningful in that the coded nature of tools and materials can (un)invite students to learning (Peppler & Thompson, 2024).

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