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Negotiation of Epistemological Understandings and Teaching Practices Between Primary Teachers and Scientists about Artificial Intelligence in Professional Development

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Abstract
While technology advancement and scientific innovation have created new topics and fields of inquiry in STEM education, external content experts such as university scientists/researchers have been increasingly involved to enhance K-12 teachers' disciplinary understandings and professional development (PD). However, few studies have scrutinized scientist-facilitated PD programs regarding teacher epistemology, about *how* and *in what ways* the programs impact teachers' epistemological understandings of disciplinary knowledge. To address the gap, this paper investigates the process by which teachers construct epistemological understandings and teaching practices in interacting with scientists. Informed by theories of epistemic cognition and social cognition, we conducted an interactional ethnography in a school-university partnered PD program with six primary teachers. Based on participant observation, teacher interviews, and classroom videos and artifacts, we identified three patterns of teacher-scientist negotiation: reciprocal negotiation of knowledge presentation, observation and interpretation of scientist practices, and inconsistency in knowledge translation. The teachers' professional responsibility and knowledge served as a critical filter in their decisions of selecting, interpreting, and rejecting scientist inputs, leading to respective epistemological stances and pedagogical actions. The research uncovers the situated and multifaceted negotiation of teacher epistemology and offers implications for researching and supporting their epistemological development.

Keywords Primary teachers · Professional development · Artificial Intelligence · School-university partnership · Teacher epistemology · Classroom teaching

Introduction

External content experts from universities (scientists or researchers) have been increasingly involved to support the professional development (PD) of STEM teachers in K-12 schools (Nelson, 2005; Ralls et al., 2018). This trend is largely driven

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by the rapid technological advancement and scientific discoveries, where new knowledge and blurred discipline boundaries urge teachers to continuously enhance their disciplinary understandings (Kelly et al., 2008). Teacher PD programs facilitated by university scientists are proven effective in improving teachers' content knowledge, teaching practice, and confidence (Clifford et al., 2008). Evidence also suggests that interactions with scientists can expose teachers to practices of scientific inquiry and domain-specific knowing and trigger their transformation towards constructivist, inquiry-based learning (Mansour, 2015; Tanner et al., 2003).

Teacher-scientist interactions may provide an important but often overlooked context in which teachers access and make sense of the nature of knowledge and knowing — the epistemological aspect of disciplinary knowledge. However, such a sense-making process and its impacts on teacher epistemology have been rarely examined in the past. Existing research has focused on the design and evaluation of *explicit* training/intervention, such as explicit reflection and knowledge calibration (Abd-El-Khalick & Lederman, 2000; Brownlee et al., 2012). Limited attention has been paid to the iterative and ongoing process, by which, teachers negotiate and construct epistemological understandings with external content experts like scientists. A major pitfall might lie in the methodology: as teachers and scientists bring differentiated expertise, their interactions might be highly complex and dynamic, hence difficult to be examined empirically (Nelson, 2005).

To address the gaps, we propose a present study to examine the process and pattern of teacher-scientist negotiation regarding personal epistemology and teaching practice. Drawn upon the theories of epistemic cognition and social cognition, we develop a theoretical framework for examining the negotiation process by tracing teachers' meaning-making and practice construction across the contexts of PD program and classroom teaching. Guided by the framework, we conduct an interactional ethnography based on a school-university partnered PD program that involves six primary teachers of Computer Science. The inquiry is guided by two research questions as follows:

1. How and in what ways do the teachers construct their epistemological understandings in interacting with scientists?
2. How do the teachers' epistemological understandings impact their teaching practices?

Theoretical Framework

Teacher Epistemology in School-University Partnership

Personal epistemology is an individual's theory about the nature of knowledge and knowing (Hofer, 2001). Personal epistemology has become significant in STEM education, as students are increasingly expected to develop higher-order cognition as opposed to reproducing knowledge, to reason evidence and evaluate knowledge claims, and to make evidence-based arguments (Skamp, 2020). To meet such expectations, teachers should be equipped with appropriate personal epistemology (Brownlee et al., 2012). Literature shows that sophisticated, mature epistemologies are often aligned with constructivist teaching encouraging student inquiries and knowledge creation, while naïve, premature epistemologies are aligned with teacher-centered, surface-atomistic teaching (Brownlee et al., 2012). Meanwhile, personal epistemology is highly complex and sometimes environments may not allow teachers to act in alignment with their epistemologies (Many et al., 2002).

An unexplored space of teacher epistemology is teacher PD programs facilitated by university scientists/researchers. Previous studies have identified significant differences between K-12 teachers and scientists in views about the nature of disciplinary knowledge, knowing, and teaching (Clifford et al., 2008; Olitsky, 2017). While the difference may hinder collaboration, it might also contribute to "a social negotiation of ideas" (Johnston & Thomas, 1997). Nelson (2005) identifies three kinds of teacher-scientist interactions — knowledge negotiation, consultation, and rejection, while negotiation has the most potential for education transformation. Their negotiation may go beyond content knowledge to epistemology: as scientists' core mission is to create and disseminate knowledge, they can bring unique resources about domain-specific inquiry and knowing to teachers (Tanner et al., 2003; Vesterinen & Aksela, 2009). However, empirical research is too few yet to clarify their negotiation patterns regarding teacher epistemology and teaching practices, calling for more process-oriented research and detailed investigation.

A Socio-cognitive Approach to Epistemological Understanding

The studies on personal epistemology started from Perry's domain-general, stage-like developmental approach, now shifting towards a more fine-grained lens that acknowledges domain specificity and context-dependence (Hofer, 2001; Sandoval, 2009). As scholars call for approaching the cognitive and situated nature of epistemological development over the life span, the concept of epistemic cognition has gained momentum which reflects "how people acquire, understand, justify, change, and use knowledge in formal and informal contexts" (Greene et al., 2016). This conceptualization, rather than viewing personal epistemology as a system of beliefs, positions personal epistemology as "cognitions about a network of interrelated epistemic topics including knowledge, its sources and justification, belief, evidence, truth, understanding, and explanation" (Chinn et al., 2011). Epistemic cognition can occur at a topic-specific level and be changed in the short term (Braten et al., 2008; Kienhues et al., 2016). Teachers' epistemic cognition can continue to grow through their teaching experiences and professional PD engagement (Buehl & Fives, 2016).

The social-cognitive perspective may offer a theoretical lens to approach teachers' epistemic cognition in scientist-facilitated PD programs. The social-cognitive perspective ascribes human development to a dynamic and reciprocal interaction of a person, environment, and behavior (Bandura, 2001). Such reciprocal interactions are largely represented, maintained, and mediated through discourse. For in-service teachers, their epistemic cognition and teaching practice are initially influenced by their professional environments, and then are opened to new social influences through their interactions with scientists. The cross-contextual examination of teacher engagement in PD programs and classrooms can be informed by the notion of intertextuality — the interrelationship among texts in constructing meanings across space and moments (Bakhtin, 2010; Bloome et al., 2004). By examining how meanings are negotiated and constructed via discourse, we can anchor teacher epistemology in an intertextual chain of activities across time and contexts and further investigate the interplay among scientist inputs, teacher epistemology, and teaching practice.

Artificial Intelligence as an Integrated STEM Education Topic

Artificial Intelligence (AI) along with Computer Science (CS) is emerging topics in STEM education in K-12 schools (Gibney, 2016; Touretzky et al., 2019). AI, as a wide-ranging branch of CS, refers to using machines to perform intelligent tasks (Rusell & Norvig, 2003). In recent years, many AI education initiatives and curriculum frameworks have been developed globally (including the USA, Europe, China, Australia, Singapore, and others), which are intended to introduce AI knowledge to K-12 students (Wong et al., 2020). As an inter-disciplinary subject, AI lies in the intersection of science, engineering, and society, while imposing far-reaching impacts on ethics and society (Morley et al., 2020). Given its impacts and topicality, the discussion on AI has involved a wide range of stakeholders and has been bombarded with conflicting claims (Rusell & Norvig, 2003). This condition echoes with research on personal epistemology that highlights the cognition to reason, weigh, and evaluate knowledge claims for informed decision-making in social contexts.

While the research on K-12 AI education remains limited, existing evidence suggests that teacher capability constitutes a major issue, regarding the qualification of teachers to teach AI competently and effectively (Vazhayil et al., 2019; Wong et al., 2020). Meanwhile, naïve epistemologies and misconceptions about the subject matter are found common among engineering and technology teachers. For example, they have erroneously viewed computer science as digital literacy or "to think like a computer" (Fessakis & Prantsoudi, 2019; Sands, et al., 2018) and failed to differentiate engineering from science (Antink-Meyer & Meyer, 2016). To address such issues, a widely adopted strategy is to engage external content experts from universities or industries for preparing the teachers' content knowledge (Chiu & Chai, 2020). In this regard, AI education may provide a heuristic context to address our research interest in the teacher-scientist negotiation regarding personal epistemology and teaching practices.

Methodology

Guided by the theoretical framework, we adopt Interactional Ethnography (IE) to address the research questions. IE is a discourse-based ethnography that examines the social construction of insider's perspective of a group (Castanheira et al., 2000). By analyzing discourse and associated actions and artifacts, IE has been widely used in science education to uncover the meaning, understanding, and practice that are socially constructed in classrooms and PD programs (Kelly, 2021; Kelly & Green, 2019). In

Table 1 A summary of mathematical thoughts and activities included in AI lessons

Topic of AI	Mathematical thoughts and activities
Information representation and binary	Calculating the number of possible states of binary digits
Feature recognition and extraction	Representing features in a vector table
Decision tree	Construction of decision tree to solve problems mathematically (e.g., to calculate leap years);
Recommender engine	Measuring the fittingness using cosine similarity

particular, the rich data and thick description generated from IE allow us to address the research questions concerning *hows* and *negotiation process* in this study (Geertz, 2008) (Table 1).

Research Context and Participants

The study was situated in a larger research project that examined a bottom-up curriculum project in an urban school district in Metropolitan Beijing, China (also discussed in Dai et al., 2020; Lin et al., 2021). The project was initiated by primary CS teachers from two schools, a CS professor from a local R2 research university, and a curriculum specialist from the school district, with a shared interest in introducing basic AI knowledge to primary students. To fulfill the goal, a school-university partnered PD program was developed to support teachers' content knowledge preparation. The CS educator, as one of the project initiators and coordinators, had leveraged his collegiate resource and professional network to invite a group of university scientists (faculty members and postdoc researchers) as instructors/advisors for the PD program, whose expertise ranged from robotics and autonomous systems to deep learning and neural network. Six primary CS teachers from the two schools participated in the PD program and the research (Appendix Table 2). Four were male and two were female; five had 3 to 8 years of teaching experience and one with 16 years.

Three kinds of activities were organized in the PD program. The program started with a 2-week summer workshop, which provided introductory-level training. Following a curriculum integration approach, the workshop included sixteen lectures, covering the Five Big Ideas of AI — machine perception, knowledge representation and reasoning, learning, natural interaction, and social impact (Touretzky et al., 2019). Upon completion of the workshop, a survey was conducted to elicit the teachers' feedback, especially about their learning difficulties and needs. Based on the feedback, the second PD activity — ten seminars, was arranged through the fall semester to help them manage the reported difficult topics. Thirdly, after the seminars, the teachers started their 'teaching experiment' by developing one/two lessons for classroom teaching in the following spring semester. Each teacher was paired with one scientist by topic matching, where the scientist ensured appropriate presentations of content knowledge. Through the three kinds of PD activities, the university scientists played a consistent role as content experts to support the teachers' disciplinary knowledge.

Data Collection

The data collection process is illustrated in Fig. 1, including three sources, the PD program, classrooms, and teacher interviews. We conducted participant observation in the PD program by attending the workshops, seminars, and meetings among teachers and scientists (Spradley, 2016). The observation allowed us to gain firsthand perspectives about the dynamics of teacher-scientist interactions, collect artifacts, and construct field notes, while building rapports with research subjects. We also observed and video-recorded the AI lessons developed by the teachers and collected their teaching materials. Lastly, we conducted semi-structured interviews with each teacher to elicit their epistemological understandings, PD experiences, and lesson design. We interviewed the teachers in a stimulus-recall manner, where collected

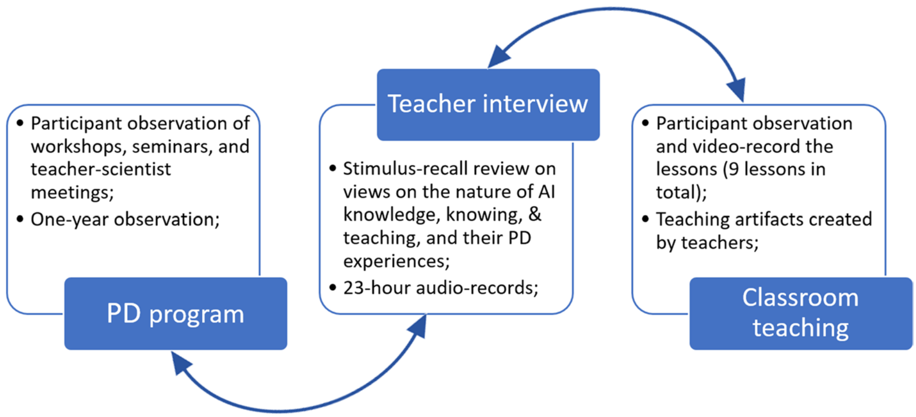

Fig. 1 Three major sources of data

artifacts were presented to aid their reflection and recounts about relevant epistemological understandings. Interview records and classroom video records were transcribed verbatim.

Data Analysis

Our analyses followed an operational cycle of ethnography: to iteratively ask a question, collect and analyze data, draw conclusions, and generate a new question from the conclusions (Spradley, 2016). During the iterative process, the oral and written discourse collected from interviews, classroom videos, artifacts, and field notes was the major data used to analyze the insider's perspective and meaning construction. Figure 2 represents the ethnographic process with three iterative cycles, along with involved discourse analysis methods.

As shown in Fig. 2, the analysis starts with and is centered on thematic analysis of field notes and teacher interview transcripts in Iteration 1, to identify teachers' ways of interacting with scientists that led to epistemological understandings. Nelson's (2005) general framework of teacher-scientist interactions was referenced initially, upon which the researcher constructed new and more specific themes. The analysis inevitably led to Iteration 2 about "*what*" epistemological understandings the teachers had constructed. The teacher interview transcripts were coded by referring to code lists of the nature of science/engineering knowledge and knowing (Pleasants & Olson, 2019; Purzer et al., 2022). Iteration 3 was simultaneously conducted to map the teacher epistemology with their teaching practices with video analysis and triangulation. Three researchers participated in the coding and thematic analysis, and their inter-coder agreement was above 82%; inconsistency in their analytical results was discussed to resolve. Based on the data analysis, a telling case approach was adopted to select the most heuristic data to illustrate the themes for data/finding presentation (Mitchell, 1984). The data analysis and findings were communicated with the research subjects for feedback and confirmation to enhance the reliability.

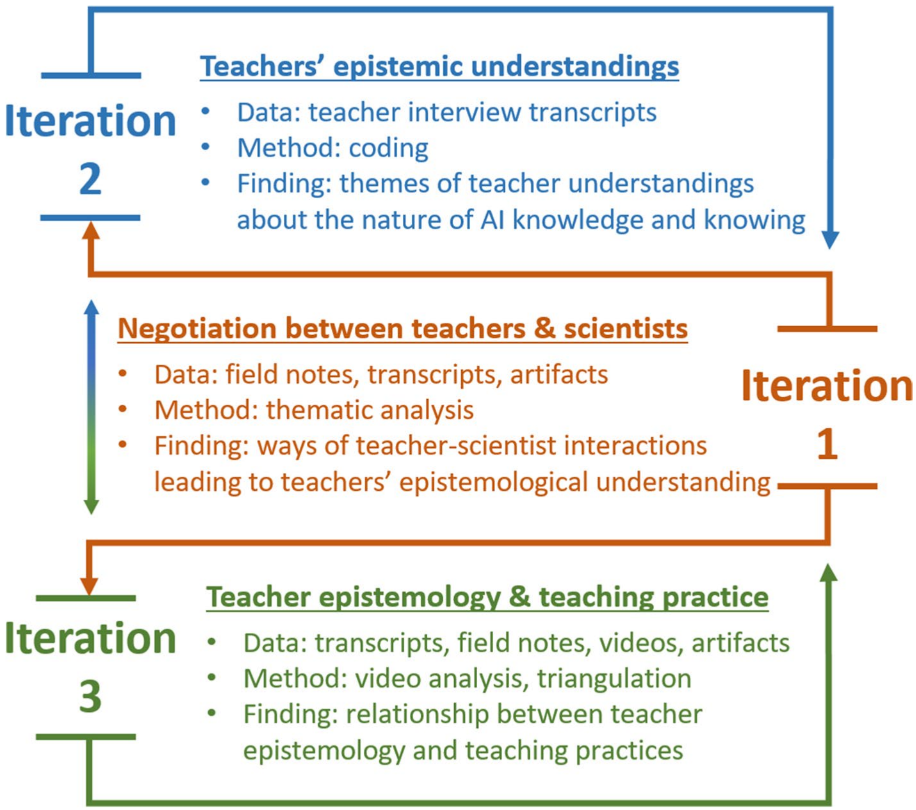

Fig. 2 The overall analytical process

Results

The research findings are presented in three themes, each with a pattern of social negotiation regarding teacher epistemology and teaching practices. The patterns are presented with *thick description*, where multiple sources of data are combined to manifest the negotiation process across stakeholders and contexts.

Reciprocal Negotiation of Knowledge Presentation

While all the six teachers held higher education degrees in engineering/technology-related majors, they saw themselves as novices or outsider to the world of AI. Once joining the PD program, they soon realized it as "almost a mission impossible" due to two reasons. Firstly, the way the university scientists delivered the AI lectures, followed a bottom-up approach that started with programming, algorithms, and computational techniques. As for the teachers, though this approach can help build up detailed understandings progressively, it was too time-consuming. Secondly, the teachers found it difficult to translate such technique-oriented contents into classroom teaching. They saw the content as highly specified and more suitable for gifted students, whereas their goal was to develop AI literacy for ordinary students.

The teachers' responses and thoughts were communicated with the program coordinator and university scientists. In balancing the teachers' needs and scientists' expertise, they agreed to shift the bottom-up, technique-oriented approach to a top-down, problem-oriented approach. That was, the scientists would leave aside the detailed techniques but start from the problem formulation — to explain how a phenomenon or a task was formulated into a technological/engineering problem that can be tackled by AI. Departing from the question, they continued to explain relevant methods, principles, and strategies for problem-solving. In this way, they hoped to make the workshop more attainable for the teachers, while helping them take up the essence of AI knowledge for classroom teaching.

Informed by the scientist inputs, the participating teachers demonstrated a problem-oriented view of the nature of AI knowledge and knowing. When interviewed about what counted as AI or learning AI, a salient theme was an engineering way of thinking about problems. For example, they described AI as "ways of thinking and performing tasks", "logic of design", "problem-solving strategies", "thoughts behind the technical solution", and so forth. Their descriptions suggest that: AI was regarded as a subject of thinking and problem-solving instead of a subject of facts or techniques; design and logic reasoning lie in the essence of AI-related problem-solving; AI can be understood by rediscovering its underlying thinking and design as well as the problem-solving strategy.

Consistent with their epistemological understanding, the teachers often emphasized problem-solving in their teaching practice. This practice can be illustrated in the following excerpt of classroom interaction, where a teacher introduced the concept of AI with a picture comparison activity. In this activity, students were shown two parallel pictures with similar problem-solving scenarios, and students were tasked to identify the problems that machines can solve.

Teacher: (pointing to the PowerPoint slide in Figure 3) so what is the problem?
Students: asking for directions.
Teacher: good try, but my question is – what problem can the robot solve?

Fig. 3 PowerPoint slide used in classroom teaching

> Student A: it solves the problem that we no longer need to ask passersby for directions; sometimes they can give you directions, but not accurate.
> Teacher: awesome! Solve the problem of accuracy in giving directions, right? Yes tell me the problem directly – this is the rule. Now look at the pictures again, is it possible that this is a foreigner asking for directions?
> Students: they might speak English.
> Teacher: so the problem it solves is ----
> Students: (simultaneously) don't understand a foreign language. To understand the foreign language and respond. Difficulty in communication.
> Teacher: yes! It solves a problem about communication difficulty or language translation; people may speak different languages, but we need to understand each other before giving a helping hand.

As shown in the above interaction, the teacher had constantly and deliberately emphasized the problem-solving nature of the AI-empowered robot. Though the students were initially inclined to describe actions/activities, the teacher used multiple strategies (e.g., rephrasing the question, restating the rule, and using sentence starters) to orient student attentions to the problem in question. This kind of problem-oriented teaching was common among the six teachers. For example, they often situated AI concepts and technology in daily contexts of problem-solving, and their explanations about the attributes and characteristics of AI were contextualized by specific tasks or problems.

The above analysis shows the reciprocal negotiation between scientists and teachers in terms of the form and content of the PD program. For the teachers, the social influence from the scientists was neither prescribed nor inherent, but activated and reinforced by their active engagement in co-deciding the PD program design, which in turn shaped their epistemological understandings and teaching practices.

Observation and Interpretation of Scientists' Practices

The PD program enabled the teachers to observe the scientists' practices at first hand. By observing and making sense of their scientific practices, the teachers attempted to interpret and identify the nature of AI-specific knowledge and knowing. Especially, since the PD program involved multiple scientists, the teachers could compare their practices for similarities and differences, based on which, the teachers made inferences about the epistemological nature of AI inquiry.

A common practice identified by the teachers was "always include(ing) some ingredients from mathematics," such as statistical models and principles of probability. They further observed how the computer scientists organized mathematical knowledge in relation to technology:

> Math is a tool to reduce or abstract complex scenarios, for example, to model an object as a vector of weights. Then the (reduced) problem must be put back into a technical framework, to follow the operational principle of technologies and engineering design protocol; (it) can be computational or robotic technology, depending on if you're making software or a robot.

The above quote shows the teacher's epistemological understanding regarding the knowledge base of AI inquiry — knowledge about technology and engineering, while viewing mathematics and science as a ladder. Influenced by this understanding, the teachers structured their AI lessons with a focus on technologies, but also a small proportion on mathematics. Table 1 summarizes a list of mathematical thoughts/activities identified from the classroom teaching. Of note, given the understanding level of primary students, the objective was not to introduce the mathematical terminologies or theories, but to stimulate student awareness; in a teacher's words, "to start gaining a sense that math can help solve AI problems – fair enough!".

Besides the knowledge, the scope of teachers' observation was extended to the scientists' behavioral patterns, such as how they interacted with others. For example, they found that "you will never get a yes or no answer from the professors," as the professors tended to explain a problem in detail. The teachers were observant enough to notice that, even on the same topic, the opinions of professors/scientists tended to diverge and "be biased by their research expertise." The teachers were also introduced to the latest development of AI, from which they were exposed to those unresolved but critical research issues.

From the observation, the teachers captured the evolving nature of AI where knowledge was subjected to changes. They also related the relative nature with the scientists' differences: there were multiple pathways to a solution, and the inquirer's responsibility was not merely to search for *any solution* but to optimize towards *the best solution* in consideration of accuracy, effectiveness, and feasibility. In this way, they distinguished AI from those disciplines that were characterized by deterministic answers. They saw AI as a subject "for creative work" as opposed to being "cut and dry".

The teachers' epistemological understandings set a positive tone to present AI in classrooms. In introducing AI concepts or problem-solving strategies, they often added a few words to conditionalize their explanations, such as "one of the solutions/strategies," "maybe new and better methods are coming," and "you will learn some more in higher studies." This framing was also evident in error moments of AI applications during the demonstration, into which they attempted to instill an encouraging and positive attitude. For example, in using the speech-to-text translation application to manifest the topic of speech recognition, errors were common in the translated result. Still, the teacher attempted to instill a positive and encouraging attitude in viewing the errors. Therefore, he concluded the lesson by purposefully calling back the errors:

> The machine is becoming smarter and more capable. But we can also see quite some ''imperfection', right? So the machines still need more help, help from scientists and engineers – Teacher Wang (the speaker) believes that some students in our class will become one day. We can help solve the errors creatively in the future, so the machine can perform tasks in a higher quality to benefit us.

As shown in the excerpt, the evolving state of AI was interpreted strategically by the teachers as a space for creativity and future exploratory opportunity, through which, they hoped to nurture and sustain student interests in AI.

Inconsistency in knowledge Translation

Ethnographic analyses further revealed a series of inconsistency when the teachers translated scientist inputs into their epistemological understandings and teaching practices. The inconsistency was not due to the teachers' failure in comprehending scientist inputs. Instead, they purposefully rejected or reframed scientists' perspectives based on their professional knowledge and sensitivity about students and school/curriculum environments.

One telling case was the teachers' reaction to the conceptualization of acting humanly versus acting intelligently. The notion of acting humanly defines AI in relation to humans and insists that AI is to simulate human intelligence; the notion of acting intelligently treats intelligence as a general and independent attribute, and the goal of AI is to develop intelligent, autonomous agents. When the two notions were introduced to the teachers, the scientists explicitly showed their preference for the notion of acting intelligently due to its scientific significance. However, the teachers had their own judgment:

> Indeed the idea of using AI to mimic humans may not be the dominating idea. Yes, we get it. But it works better for our teaching. Firstly, it is not wrong. The major reason is students. Relating AI with human intelligence is more approachable and tangible for students. Some conceptual ideas and problem-solving strategies (of AI) are too abstract or distant for students, I need something tangible to anchor my teaching.

The quote shows that, while being aware of the difference between the two notions, the teachers allowed a certain extent of ambiguity in epistemological stances and chose the one they saw as more appropriate and accessible for students. Informed by the notion of acting humanly, they often related the AI process, logic, and strategy to human cognition, through which, they created an analogy to facilitate student learning. Figure 4 is a screenshot taken from the in-class game titled *Guess Who*, which was designed to explain the mechanism of feature extraction and machine perception.

The Hearer, while back facing the class, tried to guess who the Speaker was, only through the Speaker's voice. In the process, the teacher guided the students to reflect on the cognitive actions they performed in identifying the source of a new voice: (1) analyzing and extracting key features of the voice; (2) mapping the extracted features with those stored in the brain; (3) retrieving the source/speaker of the features stored in the brain. Using students' cognitive actions as an analog, the teachers naturally slid to the corresponding AI concepts, i.e., feature extraction and database query. By juxtaposing human intelligence and AI, the teachers hoped to transform the students' self-understandings into AI understandings through guided reflection and analogical reasoning.

Fig. 4 Screenshot of classroom interaction

Another kind of inconsistency existed between teacher epistemology and teaching practice, especially concerning the assessment method. As the teaching of AI contents was still "a teaching experiment" (often part of the school-based curriculum), the teachers chose not to adopt any paper-and-pencil test; instead, they relied on formative, qualitative observations of students' class participation. However, analyses revealed that they held conflicting views regarding the current assessment practice — whether they should move from the existing qualitative system to a more quantitative system that would foreground numerical scores as a summative measurement of achievement. Their struggle was deeply rooted in the local school culture and curriculum environment.

For the pro-quantitative teachers, quality control was their primary justification, that was, to arrive at a definitive mark as the indicator of student performance and the driver of systematic quality assurance. This position was coupled with some complaints about the current practice — "too casual and subjective, lacking an objective standard to track student progress comparably, and it sends the wrong message to the students and school." Such complaints reflected the teachers' tendency for more strictly enforced outcome-based education that was characterized by specific standards of common, objective performance indicators. Their stance was largely driven by the examination-oriented culture that is prevalent at local schools, where standardized tests and high-stake evaluations were common. Under this culture, a quantitative assessment system was believed to urge schools and students to treat AI subjects seriously and secure school resources.

In contrast, the pro-qualitative teachers questioned the feasibility of quantitative and standardized assessment by revisiting the epistemological nature of AI — the conditional and relativist nature of knowledge and therefore the provisional and plural nature of judgments in teaching AI. When the knowledge in question remained neither unquantifiable nor exact, a quantitative assessment system seemed to be "a mismatch" or "a long shot". They further argued that, though the constructed-response question or design projects might be more suitable to assess AI knowledge, the associated workload would be "too much for both parties (students and teacher)". After all, most primary students were still too premature to verbally articulate AI concepts and handle such complex tasks. As for the teachers with an average workload of 15–18 lessons per week (30–40 students per lesson), grading additional work with open-ended answers would constitute a too heavy burden to carry.

The two kinds of inconsistency make visible the significance of teachers' professional knowledge in (re)shaping their epistemological stances and pedagogical decisions. Their sense-making of scientists' inputs was mediated and filtered by their professional knowledge about students, curriculum environment, and school culture, through which they translated their PD gains into teachable contents and practices in the local contexts.

Discussion and Conclusion

The research findings show the process and patterns of how in-service teachers negotiated their epistemological understandings and teaching practices in a scientist-facilitated PD program. Rather than simply following the program design, the teachers had actively engaged themselves with the scientists, the presented knowledge and practice, and their teaching profession. The teachers' professional responsibility and knowledge served as a critical *filter* in their decisions of selecting, interpreting, and rejecting the scientists' inputs for epistemological understandings and teaching practices. While the thick description uncovers the complexity and dynamics of teacher-scientist interactions, it also presents detailed and multifaceted accounts about the situated construction of epistemological understandings and teaching practices, as the teachers switched between the contexts of the PD program and classrooms.

The research provides insights into the epistemology development of in-service teachers. Rather than being a tabula rasa, the in-service teachers approached the intellectual resources provided by external experts with a pragmatic and practical mentality (Broad & Evans, 2006; Burke et al., 2021). Such a pragmatic stance, on the one hand, enabled the teachers to effectively relate the external resources with their professional engagement; on the other hand, it might have hindered their epistemology change if they fail to capture immediate relevance. In this regard, the scientist-facilitated PD program might be integrated with professional learning communities or collaborative inquiry, in which teachers and external experts can extend their epistemic negotiation to teaching and learning.

This research has certain limitations. Firstly, due to the self-initiated nature of the PD/curriculum program, the teachers had demonstrated a high level of autonomy, motivation, and willingness to collaborate with the scientists. Their proactive engagement might not be common in ordinary PD programs. Secondly, the analysis of teachers' epistemological understandings relied on their accounts and interviews. Given the research context of an introductory-level AI curriculum for primary students, the major contents in the PD program and classroom teaching were basic or "shallow". The lack of inquiry-related contents made it challenging to examine the AI-specific practical epistemology of teachers/students.

More empirical research will be conducted to enhance understanding of teacher epistemology. Building upon the present research, we have extended the inquiry to teachers' professional identity, about how their collaboration with scientists shapes their epistemic stance, positioning, and self-concept in schools. Additionally, we will expand the research scope to the epistemic climate in classrooms. While the present research shows teachers' epistemological development in the PD program, we will further explore how it might transform the teaching–learning dynamics as well as students' epistemic cognition and practice.

Appendix

Table 2 A summary of research subjects of primary teachers

Name	Gender	Education background	Years of teaching experiences
Andrew	M	B.S. in Electronic Engineering	3 yrs
Bob	M	B.S. in Mechanical Engineering	5 yrs
Chloe	F	M.A. in Information Management	6 yrs
David	M	B.S. in Computer Science	6 yrs
Emily	F	B.S. in Computer Science	8 yrs
Frank	M	B.A. in Information Management	16 yrs

Declarations

The research has been approved by the Survey and Behavioural Research Ethics Committee at the Chinese University of Hong Kong. We have no conflict of interest to declare.

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