

RESEARCH ARTICLE

Collaborative construction of artificial intelligence curriculum in primary schools

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Abstract

Background: The recent discussion of introducing artificial intelligence (AI) knowledge to K–12 students, like many engineering and technology education topics, has attracted a wide range of stakeholders and resources for school curriculum development. While teachers often have to directly interact with external stakeholders out of the public schooling system, few studies have scrutinized their negotiation process, especially teachers' responses to external influences, in such complex environments.

Purpose: Guided by an integrated theoretical framework of social constructionism, this research examined the process of *how* a teacher-initiated AI curriculum was constructed with external influences. The research focused on teachers' perspectives and responses in mediating external influences into local schools and classrooms.

Methods: A 3-year ethnographic study was conducted in relation to an AI curriculum project among 23 Computer Science (CS) teachers from primary schools. Data collected from ethnographic observation, teacher interviews, and artifacts, were analyzed using open coding and triangulation rooted in the ethnographic, interpretivist approach.

Results: Three sets of external influences were found salient for teachers' curriculum decisions, including the orientation of state-level educational policies, AI faculty at a partner university, and students' media and technology environments. The teachers' situational logics and strategic actions were reconstructed with thick descriptions to uncover how they navigated and negotiated the external influences to fulfill local challenges and expectations in classrooms and schools.

Conclusions: The ethnographic study uncovered the dynamic and multifaceted negotiation involved in the collaborative curriculum development, and offers insights to inform policymaking, teacher education, and student support in engineering education.

KEYWORDS

artificial intelligence, curriculum development, primary school, teacher agency

1 | INTRODUCTION

The rapid development of artificial intelligence (AI) technologies and their far-reaching impacts on the modern society have prompted AI as a significant topic in the global landscape of Science, Technology, Engineering, and Mathematics (STEM) education (Touretzky et al., 2019; Welk, 2020; Wong et al., 2020). According to a survey by the Organization for Economic Co-operation and Development (OECD) (2022), more than 60 countries have issued national AI policies or strategic development plans, where school education has been promoted, as a prioritized means, to strengthen the AI talent pipeline (Dutton et al., 2018; Schiff, 2021). The growing enthusiasm for AI education has permeated the K–12 sector, as policymakers and educators have been exploring approaches and guidelines (e.g., Australian Government, 2021; European Commission, 2020; House of Lords of the UK Parliament, 2018; State Council of China, 2017) to prepare the young generations for a future that is increasingly reshaped by AI. The significance of AI education has also drawn interest from external bodies other than schools, such as universities, scientific centers, and industrial actors, leading to new curriculum approaches, such as school-university or school-industry programs (Dai, 2022; Kandlhofer et al., 2019).

The complex curriculum development environment exemplified by AI education appears to be increasingly common in precollege engineering education (Andrée & Hansson, 2019; Gillen et al., 2021). The planning and development of engineering education policies and programs often goes beyond the public schooling system and is participated in by various external agencies (Olitsky, 2017; Tytler et al., 2017). Their involvement brings both opportunities and challenges to schoolteachers: they are provided with more resources for curriculum development, but also have to cope with diversified and sometimes conflicting voices (Margot & Kettler, 2019; Morrison & Fisher, 2018). Nevertheless, very few studies have investigated how teachers respond to external influences in creating school-based curricula, as teachers are traditionally presumed to merely *deliver* an already designed curriculum and narrowly focus on the classroom implementation (Tyler, 2013). Such a presumption is problematic, especially given the fact that teachers are increasingly required to act as agents of curriculum change (Balgopal, 2020). How they perceive, interpret, and respond to external influences is likely to shape the coming-into-being of a curriculum in the situated context. Therefore, it is necessary to extend the inquiry beyond school boundaries and into the interplay between external influences and teachers' responses in an iterative curriculum development process. Our 3-year ethnographic study aims to address this research gap.

The ethnography focused on a teacher-initiated curriculum project, where a group of 23 primary Computer Science (CS) teachers co-developed a new AI curriculum in Beijing, China. The research was guided by a collection of social constructionist theories about curricula, stakeholders, and teacher agency that emphasized the situated and relational construction of curriculum practices among participants. Through a 3-year inquiry, we sought to uncover how the teachers navigated the complex environment of external influences and local systems in the curriculum development process. Based on the empirical findings, we will discuss the implications for research and practice in precollege engineering education.

2 | LITERATURE REVIEW

2.1 | The complex environment of K–12 AI education

The growing enthusiasm for integrating AI into school subjects in the K–12 sector may be explained in light of the AI talent shortage prevailing across the world (Gibney, 2016). In government/industry reports of many countries (e.g., the United States, China, Australia, etc.), this talent shortage issue has been often presented as a barrier to a competitive and dynamic knowledge-based economy and even a top national security priority (Allen & Chan, 2017). Under these circumstances, AI education has been opened up as an arena for a variety of stakeholders and agencies. AI education policies and curriculum planning have been a part of wider public discussions and driven by the competition for global leadership in AI technologies and industries (Zwetsloot et al., 2019). Consequently, relevant curriculum frameworks

are designed to achieve competing and oftentimes paradoxical social and economic goals, such as improving economic competitiveness, social mobility, and equity in heterogeneous populations (Robertson & Dale, 2015). School curricula are also re-configured to focus on the development of workplace skills and competencies needed for living and succeeding in modern and complex societies (Zouda, 2018).

Despite the policy advocacy, AI education in the K–12 sector is still in the experimental stage, and there has been no universal consensus nor general agreement on the approach and principles of curriculum development (Touretzky et al., 2019; Williams et al., 2019; Wong et al., 2020). AI is often positioned in the framework of Computer Science (CS) or Technology Education, but how existing CS teachers can be (re)trained to teach AI competently remains an unsolved challenge (Tkacova et al., 2020; Vazhayil et al., 2019; Wong et al., 2020). Meanwhile, a shortage of qualified AI talents is a major issue on a global scale, making it difficult to recruit qualified, specialized teachers (Winick, 2017). As AI is a highly sophisticated subject, many schools choose to partner with external AI experts from local universities and industries (Tseng et al., 2021; Vartiainen et al., 2020). For example, a primary school in Australia invited an AI researcher, as part of a government-sponsored program named Scientists in Schools, to co-deliver AI courses with K–6 teachers (Heinze et al., 2010). Also, external experts, through professional development programs based on university-school partnerships, can be engaged to support teachers' content knowledge preparation and strengthen school capability (Chiu & Chai, 2020; Dai, 2022).

Various perspectives and agendas have permeated the school walls and influenced the teachers' perception and understanding of AI. Surveys of teachers' perceptions show that their knowledge of AI has been broadly influenced by media coverage and hype topics of AI, as opposed to being reliant on traditional teacher education programs or curriculum documents (Haseski, 2019). Likewise, due to the media influence, many teachers place great emphasis on the social and ethical dimensions of AI and viewed the socio-cultural knowledge as an imperative component of AI disciplinary knowledge (Lindner & Romeike, 2019). Meanwhile, more and more school-based curricula are shaped by industrial and commercial actors from the private sector. For example, many schools partner with technology companies to provide authentic field experiences for students (AlQarzaie & AlEnezi, 2022; Cersonsky et al., 2017). Educational resources produced by commercial actors, such as textbooks and learning software, are rapidly entering classrooms (Andrée & Hansson, 2020). While the boundary-crossing exchange is becoming common in precollege engineering education, few studies have examined how such exchanges shape the school curriculum and classroom dynamics.

Amid this complex environment, student populations have also been changing, which further complicates teachers' work (Warschauer et al., 2004). In the context of AI and engineering education, students' technology usage outside school has become common globally (Bers et al., 2012; Mumtaz, 2001). Especially in the upper-middle-income and high-income countries, the percentages of school-aged children with Internet access at home are 60% and 86%, respectively, and the percentages are even higher in urban areas, 77% and 88% respectively (UNICEF, 2020). Their technology access is significantly correlated with their learning in technology-related subjects and digital/technology literacy development (Bozionelos, 2004; Vekiri, 2010). However, a student's access to technology is largely determined by their socio-economic background and parental attitude, which can lead to educational inequity and socioeconomic achievement gaps (Lei & Zhou, 2012; Warschauer et al., 2004). For example, Kenway (2013) found that students may be disadvantaged in classroom participation if their parents could not afford or refused to pay for learning devices like computers and tablets.

2.2 | A social constructionist perspective of curriculum development

The complexity and dynamics of AI education highlight a need for detailed scrutiny of the curriculum development process in its situated context, focusing on *being*, *becoming*, and *enacted* rather than merely on the final product (Brown et al., 2012; Chval et al., 2014). The need echoes a social constructionist perspective in curriculum studies (Edwards, 2011; Leander & Osborne, 2008). Social constructionism, which was rooted in the social construction of reality in sociology (Berger & Luckmann, 2016), argues that social realities and human actions/ideas shape each other (Maton & Moore, 2009). From this perspective, a curriculum is not predefined or prescribed from top-down, but socially constructed and enacted among participants in a situated context (Gee & Green, 1998; Priestley & Philippou, 2018). The social construction process resonates with the stakeholder theory that addresses interests and interconnections among stakeholders within an organization or group (Friedman & Miles, 2002). Informed by the stakeholder theory, curriculum development can be conceptualized as an evolving dialogue between stakeholders with different interests, beliefs, and commitments to education, where they collaboratively navigate, negotiate, and construct new meanings and

practices (Benavot & Resh, 2001; Kelly et al., 2000). Therefore, it is imperative to approach the process of their interaction and negotiation as they collaboratively construct meanings and practices of a curriculum.

From the social constructionist perspective, any form of curriculum change is “a socially bounded process,” subject to cultural norms and societal values in the situated context (Dimmock & Walker, 2005, p. 1). With respect to AI education, to develop a novel curriculum can be seen as an effort to initiate a curriculum change in response to policy orientation, societal change, and technological development (Priestley, 2011). There are three approaches on curriculum change: the *mandatory* top-down approach, *voluntary* bottom-up approach, and *collaborative* approach (Fullan, 2000; Setiawan, 2020). In any of the three approaches, there are three areas of factors that affect the success of changes: characteristics of the change, local characteristics, and external factors (Fullan, 2001). The three areas are interdependent, whereby stakeholders from local/internal systems and external agencies have to negotiate iteratively before deciding whether to embrace or reject a change.

To approach the interaction between participants and the situated environment, the social constructionist perspective orients our attention to the notions of agency and structure (Archer, 1999). Teacher agency refers to teachers' professional capability to act purposefully and constructively and take ownership of changes (Priestley et al., 2013). Recent studies have cast teachers as agents of STEM curriculum change, as teachers play a key role in realizing and enacting changes in classrooms (Balgopal, 2020; Birt et al., 2019; Larkin et al., 2009). Even under the most prescriptive “teacher-proof” curricula, teachers rarely implement or deliver a curriculum as strictly instructed by the policy; but rather, they translate, interpret, negotiate, and mediate it (Braun et al., 2010), “in the light of their own knowledge, beliefs, and attitudes” (Posner, 2004, p. 13). Teacher agency has been found critical in ensuring the success of curriculum change; without professional agency, many teachers tend to stick to their routine activities and refuse to adopt new practices due to the cost and uncertainty of change (Fullan, 2001; OECD, 2016). A critical step for teachers' agentic engagement is to make sense of new and often complex ideas embedded in a new curriculum; otherwise, they tend to revisit existing practices and ways of thinking (Braun et al., 2010).

Informed by the integrated theoretical framework of social constructionism, we adopted an ethnographic approach to examine how teachers respond to a complex curriculum environment of external forces and local challenges in school-based AI education. The research can shed light on AI education and more broadly engineering education, as well as clarify teachers' role and engagement in the collaborative curriculum development. The ethnographic methodology was chosen because it offers a practical and flexible approach to interpreting complex, unstructured social phenomena *in situ* and provides a sound intellectual justification for developing conceptual understanding based on grounded observations (Agar, 2006). Specifically, we formulated the following research questions (RQ) to guide our inquiry:

- What external influences do teachers consider in constructing a primary AI curriculum?
- In what ways have the teachers (re)shaped the AI curriculum in consideration of these influences?

3 | METHODOLOGY

Ethnography has been adopted as the logic of inquiry to guide this 3-year research. In research, ethnography is used as both an epistemology and a research method (Agar, 2006). *Ethnography as epistemology* is a non-linear system guided by iterative, recursive, and abductive reasoning (Anderson-Levitt, 2006; Green et al., 2012), where ethnographers pursue lines of inquiry based on *in situ* observations and discoveries (Anderson-Levitt, 2006). The goal of ethnography is to uncover the insider's meaning and practice constructed within a social group (Green et al., 2005; Walford, 2008). Particularly, we followed a *telling case* approach of ethnography (Mitchell, 1984). Rather than pursuing generalization from typical or representative cases, a telling case prioritizes the heuristic value of complex or even extreme cases in which ethnographers seek to make visible conceptual relationships between behaviors, events, and/or phenomena for theoretical inferences (Andrews, 2017). In this ethnographic research, we aim to construct a telling case from a teacher-initiated curriculum project to discuss teachers' responses to external influences in complex curriculum environments.

3.1 | Research context and participants

The research is situated in an ongoing teacher-initiated AI curriculum project that started in August 2018 in Beijing, China (also discussed in Chai et al., 2021; Dai, 2022; Dai et al., 2020; Lin et al., 2021). A significant context of this AI

curriculum project is the education policy environment in China. In the national context of China, the effort of systematic AI education is often traced back to 2017, when the *New Generation of Artificial Intelligence Development Plan* policy was issued by the State Council of China (2017). This policy clearly outlined a plan to develop an official curriculum guide on AI for both primary and secondary education. In early 2018, a revised version of the senior secondary curriculum standard was published, in which AI was added as a module of selective compulsory content with specific learning targets and expectations. Meanwhile, an official proposal was issued by the Ministry of Education of China to develop a curriculum standard for primary education. Although the official curriculum guidance was not issued then, the policies encouraged a group of teachers to explore the potential of teacher-initiated curriculum on AI.

The AI curriculum project in which this study is situated can be traced to a voluntary “teaching experiment” by six primary teachers in Computer Sciences (CS) from an urban school district in Metropolitan Beijing, China. The teachers took the initiative to integrate fragmentary AI concepts and popular gadgets into their CS classrooms. While the positive student responses and classroom experiences encouraged them to continue the teaching experiment, they also saw a need for additional resources and supports to improve their practices. Under these circumstances, the six teachers, along with a curriculum specialist from the school district and an engineering professor in robotics from a local R2 research university, formed a partnership to develop a new AI curriculum for Grade 4–6 primary students. The teachers also applied for a seed grant from the school district to sponsor their AI curriculum project.

The curriculum development was accompanied by professional development (PD) for the participating teachers. The engineering professor had organized a series of workshops on AI and helped the teachers improve their subject content knowledge. While translating their knowledge into curriculum design, they tested their design ideas in classrooms for immediate feedback. They also referred to existing programs and textbooks for inspiration (e.g., Sensetime, 2018; Touretzky et al., 2019). After 1 year of iterative design and revision, the project team created the first curriculum version with 10 learning modules. This was sent to a panel of AI educators and curriculum experts for external review; the expert feedback focused on curriculum visions and contents. Meanwhile, the PD workshops were widely promoted among primary CS teachers within the school district. By 2020, the project team included 28 teachers, among whom the curriculum was circulated for implementation and testing. All teachers were encouraged to design new pedagogical activities for classroom teaching, and the newly designed activities were also collected by the project team to refine and enrich the pedagogical part of the curriculum.

Through an open call to all 28 teachers of the situated AI curriculum project, we recruited 23 research subjects who were willing to participate in individual interviews and to be observed in classroom teaching. The 23 teachers worked in 16 primary schools and had been teaching AI for no less than 1 year. Sixty-two percent and thirty-eight percent of the teachers were female and male respectively. Over 90% of them had more than 5-year working experience as CS teachers, and over 80% held bachelor's degrees in computer science, information science, engineering, and other related majors. All 16 schools were public schools within the same school district. According to the city-wide standardized assessment, student performance of the schools is usually ranked among the top 60% and 20%. The class size of the primary schools is approximately 40 students, as regulated by the city's education authority.

3.2 | Curriculum overview

Table 1 shows the AI curriculum after revisions, including the overarching aims and learning contents and objectives in the 10 learning modules. The overall design followed a *curriculum alignment* approach (as per Anderson, 2002)—to vertically and horizontally align the curriculum with learning paces and expectations of Grade 4–6 primary school students (age 10–13). The 10 learning modules, while kept consistent with the curriculum aims, were deliberately designed as relatively independent blocks: each module was designed with a duration of 40–80 min (i.e., one to two lessons) conditional upon student levels and local resources, affording teachers the flexibility to adopt either a selection of modules or the entire curriculum.

3.3 | Positionality

Upon the establishment of the AI curriculum project, the first and second authors of this article were introduced by the engineering professor who co-initiated the project, as external evaluators. By engaging external evaluators, the engineering professor hoped to gain critical and impartial opinions from outsiders, especially those with educational

TABLE 1 An overview of the focal AI curriculum

Curriculum aims	
Students will be able to:	
• Understand the basic concept, process, and problem-solving strategy of AI; • Use AI strategies and applications to solve problems in everyday life; • Develop a responsible attitude and critical thinking to understand and apply AI.	
Learning content/topic	Learning objectives
1. Intro to AI and AI in our everyday life	• To understand the attributes of intelligence and AI; • To recognize AI applications in everyday life.
Data and knowledge representation	
2. Binary numbers and pixels	• To understand the concept of binary numbers and pixels; • To apply binary numbers/pixel to code daily information.
3. Data and knowledge representation	• To sensitize the process of encoding and decoding; • To create basic numerical and visual forms of data; • To comprehend relations between codes, data, knowledge; • To understand limitations of binary numbers and quantitative data.
Machine perception	
4. Machine sensor	• To understand regular sensors used in AI; • To differentiate machine and human sensors/sensing; • To connect sensors with binary numbers/pixels.
5. Data collection from sensors	• To understand basic methods of sensor data collection; • To sensitize the process of data communication; • To understand the attributes of big data.
6. Pattern recognition and privacy concern	• To understand the basic process and strategies of pattern recognition; • To understand its application in image and voice recognition; • To analyze potential security & privacy issues.
Machine reasoning	
7. Algorithms and potential bias	• To understand the concept and attributes of algorithms; • To construct flow charts to represent algorithms; • To understand causes of algorithm bias.
8. Decision tree	• To understand the attributes and structure of a decision tree; • To construct diagrams to model decision trees.
Machine cognition	
9. Data training and machine learning	• To understand the process of data training/modeling; • To connect machine learning with everyday problem-solving.
10. Strong and weak AI	• To differentiate attributes of strong and weak AI; • To understand limitations and future directions of AI; • To gain a responsible attitude and critical thinking about AI.

research experiences. To avoid conflicts of interest, they agreed upon a *goal-free evaluation* model (Scriven, 1991); that is, the first and second authors would observe, document, and measure the actual process and outcome of the curriculum project, intended or unintended, without being constrained by the project aims. The first author, who had over 5 years' experience working as an education ethnographer in STEM education by the time the project was initiated, conducted participant observation and led the data collection and analysis. The second author, an engineering professor with expertise in AI-based engineering design and engineering education, has contributed to the data analysis and interpretation with domain-specific knowledge of AI. The research team included tenure-track researchers with 5–20 years' experience of STEM education research and program development, and full-time research assistants with postgraduate degrees. Approximately, half of the team members had postgraduate degrees in AI-related engineering subjects. As the research project continues to grow, the first author has engaged more colleagues from her affiliated department to support the research activities.

3.4 | Research process and data collection

Participant observation has been conducted by the first author as an embedded ethnographer (Spradley, 2016a), who has been attending the AI workshops and project meetings in person and online. The participant observation helped the ethnographer build trust and rapport with the teachers and also enabled her to understand the culture and practice being constructed within the project team. Besides, the ethnographer observed over 40 lessons delivered by 14 teachers, as a way to obtain first-hand experiences of the AI curriculum enacted in classrooms. Between February 2020 and April 2021, affected by the global pandemic of Covid-19, the observation was conducted virtually through videoconferencing and documented in the format of fieldnotes. Throughout the process, the ethnographer collected a series of artifacts created by the teachers, including curriculum documents, textbooks, lesson plans, PowerPoint slides, and other relevant teaching materials. These artifacts served as externalized, written records of the teachers' perspectives and practices in developing the AI curriculum.

Ethnographic interviews were conducted via individual and focus-group interviews to directly elicit the teachers' perspectives and experiences (Spradley, 2016b). Specifically, individual interviews were conducted with all 23 participating teachers after 6 months of fieldwork and casual conversations, when the ethnographer had developed sufficient knowledge and trust with the teachers/insiders. During the interviews, the teachers were elicited to describe and reflect on their understanding, opinions, and practices in constructing the AI curriculum in relation to the external actors and agendas. Each individual interview lasted for approximately one hour. Some sample questions included "Why did you join this curriculum project?", "Could you please describe your experiences in attending the AI workshops?", "What was your consideration in defining/designing ...?" Additionally, six focus group interviews were conducted in a semi-structured and face-to-face fashion between 2019 and 2021, with two interviews each year. The purpose of the interviews was two-folded: first, to identify common understanding and practices as well as salient topics among the teachers; second, to communicate the researchers' periodic findings and elicit teacher feedback for verification and revision. Each interview involved 6–10 participating teachers, lasting for 2–3 h. All the individual and focus-group interviews were audio-recorded and then transcribed.

3.5 | Data analysis and interpretation

Following the ethnographic, interpretivist tradition, we used inductive coding, also known as open coding, to analyze the qualitative data (Goulding, 1999; Holton, 2007). Our coding began with reading through the fieldnotes, interview transcripts, and teacher artifacts to create codes out of scratch, followed by gradually including other data to verify and enrich the coding. Based on the initial list of codes, we conducted focused coding to sort out the relationships between different codes, such as expanding the focal codes, collating the relevant codes, and distinguishing the parallel codes. Next, we reviewed the code lists by juxtaposing the data to check consistency and accuracy, refined the codes and categorization, and identified a list of salient themes. This coding/analysis process was iterative and recursive in nature, as the researchers had been constantly reading through the data and codes back and forth for verification and revision, as opposed to a linear process.

The coding reliability and validity were enhanced through collaborative analysis and interpretation within the research team. The first two authors led the coding and analysis as the coders, and they presented the draft findings to the research team on a fortnightly basis for discussion and feedback. The research subjects were also engaged to verify the findings during the focus group interviews (Spradley, 2016b). Through the continuous discussion, the code-list and analytical results were revised and double-checked to ensure consistency and reliability. Lastly, data triangulation was adopted throughout the process of data analysis and interpretation (Green & Chain, 2018) to obtain more warranted findings.

4 | RESULTS

The analytical results are presented in three sections, each representing a source of external influences that the teachers navigated within the local context of curriculum development. In each section, detailed and thick descriptions are provided to manifest the teachers' situational logics and strategic actions throughout the process. Specifically, ethnographic fieldnotes are combined with a wide range of interview transcripts (cited with quotation marks) from focus-group and

individual interviews to explain the relevant topics in a “telling” way (Mitchell, 1984). Together, the three sections constitute a comprehensive picture about the agentic construction of their intended AI curriculum in a complex environment.

4.1 | Teachers interpreted AI education policies on account of their professional positions and STEM curriculum nature

The investigation on teacher engagement started with their motivation, rationale, and intention, concerning why and for what reasons they participated in the AI curriculum project. The ethnographic analysis showed that, while the education policy and associated topicality had triggered teacher awareness and interest, they did not simply follow the policy by a top-down approach. Instead, their professional role and sensitivity as CS teachers had urged them to take up the opportunity to change the marginalized status of CS subject, leading to their unique vision and goal for the intended AI curriculum.

4.1.1 | Strategic adoption of policies in favor of professional status

As recalled by many participating teachers, the relevant education policies as outlined in the research context were a “wake-up call” that drew their attention to AI education. The CS teachers were sensitive to these policies, as their course “was often seen as the closest to AI education.” Such policies, while serving the purpose of educational planning at national level, were not mandates for teachers’ actions, but had stimulated and raised their awareness of AI education. They regarded the policies as “a signal as well as a beginning,” which not only encouraged but also assured them of the legitimacy of a pilot project on a teacher-initiated AI curriculum.

The vast attention paid to AI education in educational policies and public discussion formed a sharp contrast with the marginalized status of the CS subject in primary schools. The teachers explained that, compared to the core subjects such as Chinese/English Language Arts and mathematics, CS was an optional subject—“often seen as far less important.” Due to the policy orientation, they recognized that “the CS subject is gaining more momentum than ever before, not only within the education sector, but from the perspective of national development.” Under this circumstance, AI education appeared as a chance to change the marginalized status of CS subject. A teacher explained their rationale as follows:

The CS subject and teachers have not received sufficient attention, nor been really taken seriously in schools. The current curriculum framework is centered on core courses, and the CS subject, as an optional course, is the marginalized among the marginalized. For example, when there was trouble in scheduling the teaching timetable, the teaching time of a CS course would be shortened or replaced by the core courses. As for the CS teachers, in addition to the regular teaching duties, we often need to take on other non-academic responsibilities, for example, managing a computer lab in the capacity of an IT technician, troubleshooting and maintaining digital facilities, and other assigned duties. So, when there is a chance for change, we definitely want to give it a try.

The above interview portrays CS teachers’ dissatisfaction with the marginalized status, as a consequence of which they were unable to secure equivalent resources and supports as their colleagues. Some teachers even described it as “a vicious circle” or “an embarrassing and struggling condition”: “since we do not receive sufficient resources, we don’t even have the chance to fully demonstrate the value of Computer Science; and then people would question the necessity of teaching Computer Science, leading to further resource cut.” Consequently, the national AI education policy as well as the local AI curriculum initiative emerged as an opportunity for changes, especially “to change the status quo and illustrate the unique values of Computer Science Education.”

This was especially the case considering the top-down education system in China. The attention cascaded from the central government along with the advocacy and promotion manifested in national policies, led to public recognition of the significance of CS education. Such a recognition became a positive reinforcement for teachers to take action, even without mandates. Additionally, the recognition and topicality of AI education indicated a boost in its status and future investment, which meant opportunities of career development for the teachers. On the one hand, the curriculum

change might offer chances and resources to build new professional capacity and competency; on the other hand, their proactive participation in a high-profile project like the focal AI curriculum project might elevate their career.

4.1.2 | Positioning AI as a STEM subject

With the hope to improve the marginalization of CS education, the teachers searched for potential models while reviewing the existing AI-related curricula/programs—programming and robotics. A programming curriculum is typically designed to teach students the introductory-level semantics and syntax of certain programming languages such as Scratch and Python. As for the robotics curriculum, it normally combines engineering and programming, where students learn to design, assemble, and program a robot, using a design kit with gear, motor, sensor, actuator, and other elements. On the one hand, the teachers acknowledged the strengths of these courses in introducing excitement and dynamic interactions to classrooms. On the other hand, they shared a common concern about these courses for being “highly specialized” and “too narrow-focused to be inclusive.” One interviewed teacher critiqued as follows:

A major problem with coding courses and others, is an over-reliance on a certain language or software, (which is) too operational and highly specified. (In the courses) they are trying to replicate the university training model in primary schools. But things are not so easy. (It is like that) we don't teach a simplified version of quantum mechanics or theoretical physics in primary schools, but we focus on general physics and science. Our goal is to make the AI course inclusive and accessible to ordinary students, as opposed to only gifted or advanced ones. It should be a regular STEM course: it is an academic subject matter, centered on knowledge, not just operations ... That is the unique value of the AI curriculum, which won't be easily replaced by other courses.

The interviews revealed a common concern, that too specific/narrow content knowledge may discourage the engagement of ordinary students. In particular, since coding and robotics are relatively complex subjects, the courses would likely become “an exclusive club for gifted or highly capable students.” The project team hoped to develop “an inclusive version of AI education that can benefit a wide spectrum of students.” This goal was also aligned with their attempt to improve the marginalization of CS education, as an inclusive AI course could demonstrate its unique value to most students and then enhance the students' as well as the schools' understanding of the importance of their work.

To make the intended AI curriculum inclusive and accessible, the teachers' strategy was to strengthen its academic nature by situating it in the STEM education framework. They argued that, identical to the treatment of general sciences in primary education, AI can be constructed as an academic subject with sustainable, specialized knowledge, as opposed to a series of technical operations. In particular, they regarded the AI subject as a coherent system, in which, the domain-specific knowledge should be vertically aligned to forge a progressive, step-by-step educational experience. This also alleviated the concern that AI was too difficult for primary students: all would be engaged in an easy-to-difficult learning sequence with reasonable objectives and expectations at each step. In order to align the AI curriculum with the STEM education, the teachers specified two overachieving curriculum aims: (1) to develop AI literacy with basic understandings of AI concepts and applications, and (2) to develop positive values for personal development and engagement in an AI-infused future.

The above analysis shows how the teachers negotiated and interpreted the policy in their favor, as a way to construct the goal and vision of their intended AI curriculum. Their interpretation of policy was not a linear bottom-up approach; instead, anchored in their professional role as CS teachers, they situated the AI curriculum in the complex web of policy agenda, career challenge, and curriculum environment. In balancing these factors, they identified potential space for the AI curriculum and sought to propose an inclusive version as a regular STEM subject.

4.2 | Teachers elicited resources from university faculties to negotiate the epistemic nature of the AI subject

After setting the curriculum aim and positions, the teachers were confronted with another question: what to teach and how to teach it, namely, the design of curriculum content and pedagogical approach. The subject matter knowledge was a major hindrance for their design, and therefore, the project team engaged an external body—the research

university that was seen as a fertile ground for AI research and knowledge—for the teachers' professional development (PD). As revealed by the ethnographic analysis, the teachers did not simply absorb the knowledge presented by university professors; instead, they actively explored the epistemic nature of the AI subject and negotiated the respective pedagogical approaches to fulfill their teaching needs and challenges in classrooms.

4.2.1 | Balancing expert knowledge and curriculum aims

The engineering professor, as one of the project initiators, utilized his professional network to invite multiple AI experts for a series of workshops. Most of these invitees were professors/researchers at public research universities. By interacting with the AI experts, the teachers soon realized a nuanced difference:

AI is such a sophisticated field! The professors are (so knowledgeable) as if owning a tank of water; what we teachers need to take up (from the professors) is a bucket of water; then we can give students a cup of water in our AI course.

The professional learning experience raised the teachers' awareness about the knowledge gap among AI experts, teachers, and students, respectively, "what is taught (to us), what we learn, and what we can help our students take up." The learning difficulty was not uncommon among the teachers. As one of them complained, "three professors gave lectures on convolutional neural network, before we finally understood its underlying architectures and methods." Their learning difficulty was further transmitted to their concern about the content design, which was what can be taught and what level of student understanding can be achieved. The concerns stimulated them to shift from a prescriptive view to a realistic and balanced strategy. In particular, considering their curriculum vision of making AI an inclusive subject within STEM education, they felt an urgency to "bring out the most substantial and unique knowledge about AI that students are not able to learn from other courses," while making the learning experience accessible for most students. In balancing various considerations, their strategy was to leave aside the detailed techniques and algorithms and to focus on conceptual understanding and logical reasoning.

In alignment with the above strategy, the participating teachers demonstrated a process-oriented view of the subject matter knowledge as opposed to a content-based view. When surveying their conceptions about what counts as AI, a view of AI as a unique way of seeing, thinking, and problem-solving seemed to prevail within the project team. More than 85% of the teachers mentioned the thinking underlying AI, such as "ways of thinking," "logic of design," "problem-solving strategy", "thoughts behind the technical solution", and so forth. Their descriptions suggest that: AI was regarded as a discipline of ideas and thinking processes rather than one of facts or techniques; design and reasoning are at the core of AI; AI can be understood by rediscovering its underlying thinking and reasoning process as well as the design strategy.

Influenced by this view, a participating teacher designed an in-class activity *Scoring the Objects*, which was used in the first lesson to introduce the concept of AI:

The activity involved asking students to score a set of given objects on the scale from 0 to 10, with 0 being "not intelligent at all" and 10 being 'as intelligent as humans'. I chose objects that were familiar to students, such as a wooden stick, a pencil, Siri/Xiaodu, a robot vacuum cleaner, a smart speaker, and others. When students discussed and scored these objects, I asked questions (to prompt their thinking): 'Which one is more intelligent?', 'Why do you think A is more intelligent than B?', 'What makes it intelligent?' ... When they compare, score, and rank these objects, they need to rely on their own thinking, rather than be spoon-fed.

This activity exemplified the teachers' adoption of the information-processing model, more specifically, conceptual teaching, in the pedagogical design. By using everyday examples and inductive reasoning, they gradually guided students to develop hypotheses about attributes/characteristics of the concept of intelligence, formulate and validate their hypotheses, and draw conclusions about the attributes of the concept. This teaching strategy reflects, and is aligned with, the teachers' process-oriented view of AI: the activity could uncover the formation process of AI concepts while engaging students in a focused thinking process. Additionally, the emphasis on conceptual teaching resonated with their critical stance toward the *what* knowledge (i.e., examples, facts and hands-on activities): they did not mean to

reject the *what* knowledge, but to treat them as the vehicle of learning the *hows* and *whys*—the attributes and processes behind the concepts and the logics and strategies of problem-solving.

4.2.2 | Selective interpretation of expert inputs in consideration of student characteristics

In interacting with the AI faculties, the teachers were also exposed to practices of scientific research and knowledge creation. For example, they noticed that many professors presented their research work as “one of the solutions” and made comments on some questions as “unsolved,” “still working on it,” or “we are not there yet.” Some teachers were observant enough to notice that, even on the same topic, the experts’ opinions would vary and “be biased by their research expertise.” From the observations made, the teachers learned about the provisional and plural nature of AI knowledge, and then the question became which knowledge or perspective should be presented to students.

The teachers’ curriculum decisions can be exemplified in their choice when faced with a divergence of AI conceptualizations—acting humanly versus acting intelligently. The paradigm of acting humanly defines AI with reference to humans and argues that AI should simulate human intelligence, whereas the paradigm of acting intelligently treats intelligence as a general and independent attribute and the goal of AI is to develop intelligent agents. Faced with the two different paradigms, the teachers acknowledged:

Though acting intelligently might be the dominating view in the academia, we lean towards the neuroscientist’s work, to view AI in relation to human beings. Our primary consideration is students. Treating intelligence as a symbol is too abstract, detached for primary students. In contrast, relating AI to humans is more tangible and fun.

The teacher’s account shows that, rather than embracing the professors’ views, they deliberately allowed epistemological ambiguity to accommodate student characteristics. Their choice of the acting-humanly paradigm was not to compromise on student understanding, but to situate students in a progressive, concrete-to-abstract, easy-to-difficult learning journey. In this journey, a beginning sequence with attainable and suitable contents was tailored for the young learners.

Inspired by the acting-humanly paradigm, they developed a unique pedagogical approach, which regarded humanity as the point of departure in conceptualizing and contextualizing relevant AI concepts. As such, AI was deemed as a vehicle of mimicking human intelligence and performing human cognition, whose ultimate purpose was to serve human beings for social good. A key strategy of the pedagogical approach was to start the learning about AI from self-exploration and self-understanding among students. In other words, to understand how machines mimic human intelligence, students should understand how human intelligence works prior to how AI works. Toward this objective, the cognitive process of students themselves was purposefully externalized by the teachers as a manifestation of human intelligence as well as a reference to make sense of AI concepts. The classroom game *Guess Who* exemplifies the teaching strategy, which was designed as an interactive activity in relation to the topic of “machine perception” and “machine learning,” namely, how a machine retrieves, processes, and models data. Table 2 shows the flow of student and teacher activities in the *Guess Who* game.

In this game, the blindfolded Hearer’s task was to link a voice from an unknown source with his/her familiar classmates, by recognizing and mapping the features of the voices. The game and prompt questions were intended to draw students’ attention to the human cognitive actions in the guessing process (i.e., extracting key features of a voice, retrieving familiar features encoded and stored in the human brain, and mapping the newly extracted features with those stored features to identify the source). Using human cognition as an analogue, the teachers slid naturally to corresponding AI concepts—feature extraction and database query. With the progressive activities, students were firstly oriented to reflect upon their own intelligence, about how they perceived, sensed, and recognized the surroundings and made informed decisions; then such reflective understanding was turned into a learning resource via analogical reasoning, to facilitate students’ comprehension about corresponding AI concepts or processes.

With the AI-human juxtaposition, the teachers also sought to push the AI teaching further—to forge students’ awareness and empathy about social and ethical issues. When using human intelligence as an analogy for AI, the teachers used personification to teach AI ethics—a machine may function as if being human or in a humanistic way. For example, when explaining the systemic discrimination and bias in algorithms, a teacher guided students to critically analyze the predicted results by AI and connected the computational discrimination with social discrimination, while

TABLE 2 The activity flow in the *Guess Who* game

Instructions given by the teacher	Sequential activity by student
(To the class) First we need a Hearer, who will be blindfolded with a scarf, then listen to a voice and guess who is the speaker. Who would like to be the Hearer?	A is assigned as the Hearer and gets blindfolded, standing in front of the classroom and with their back to the class.
(To the class) Now we need a Speaker, who will say something aloud. Then we will invite the Hearer, without seeing the Speaker, to guess who the Speaker is. Who want to try this role as the Speaker?	B is assigned as the Speaker quietly, while A is not informed.
(To B) Please say something aloud, anything you like, but you cannot tell us who you are.	B says something aloud.
(To A) Can you take a guess who is the speaker just now?	A makes a guess—X.
(To A) Why do you think it's X? What do you know about X's voice?	A describes the feature of the newly heard voice and maps it with X's voice.
(To the class) Is A's guess correct? (If incorrect) Let us tell A who the speaker is. What is the difference between B's and X's voices?	The class describes the similar/different features between B's and X's voices.

promoting the idea that “computers should treat users in a respectful and fair manner.” Another strategy was to put students in the victims’ shoes. For example, in teaching the topic of big data and data privacy, they would guide students to position themselves as users of smart products whose data were constantly collected with or without user’ consent. They usually used “what if ...” scenarios, such as the lack of informed consent and illegal data leak, to encourage students to brainstorm relevant risks associated with unethical practices. By navigating the ethical challenges from a first-person angle, students were more likely to comprehend the urgency and develop a more responsible attitude toward the usage of AI technologies in everyday life. In this way, the seemingly abstract, detached ethical topics were reconstructed into tangible and accessible experiences that students could relate themselves to, through which a sense of sympathy and responsibility could be fostered.

The above analysis shows how the teachers negotiated the epistemic stance and pedagogical approach from the teacher–expert interaction. In addition to the content knowledge, they were also exposed to the university professors’ practice of presenting and creating knowledge, which further enriched their epistemic understanding of AI. In harnessing the external resources, the teachers had to carefully weigh the nature of AI knowledge, curriculum aims, and student characteristics toward a balanced and creative pedagogical approach.

4.3 | Teachers redefined the role and nature of students by considering their media and technology experiences

The investigation on the teacher’s perspective reveals a significant role played by students, who were a driving force and co-constructor of the focal curriculum. The teachers’ considerations about students were not only about their psychological characteristics or understanding levels, but more importantly, about the complex social network students were embedded in, which included multiple relations and more complicated ways of interacting with teachers. Students’ differentiated but diversified access to AI-related topics out of classrooms had shaped their backgrounds, expectations, and relationship with the teachers in classrooms.

4.3.1 | A changing student population as a driving force to curriculum change

The students’ influence can be traced to their important role in many teachers’ decision of joining the AI curriculum project. More than half of the interviewed teachers attributed their participation to student needs and interests. They recalled challenging moments where students mentioned or asked AI-relevant questions in the CS course, which usually stemmed from hearing some buzzwords in the news and social media. In particular, many teachers highlighted an event—AlphaGo versus Ke Jie in May 2017, 1 year before the AI curriculum project commenced. AlphaGo versus

Ke Jie was a Go match between the computer Go program AlphaGo Master and the world No. 1 ranked player Ke Jie, in which AlphaGo defeated Ke Jie in all three games. As the game was staged in Eastern China and the player Ke Jie was Chinese, the computer–human game not surprisingly became a media event that received massive public attention and response in China over an extended period of time (Google Trends, [n.d.](#)). A teacher recounted his observation of students' reactions during and after the game days:

Everyone was talking about it, on TV, mobile apps, on the screens in the bus and metro stations, it was everywhere. AI beats humans? So shocking! Our students also heard about it and talked about it. It soon became something I could not avoid (in my CS course). Students came to ask me why AlphaGo was so powerful, what reinforcement learning was. Also, many other questions, for example, if AI was really going to replace humans, will one day AI be too smart to be controlled by humans, questions and stories they had learnt from the media and science fiction movies ... In some other courses, for example, the Chinese Language Arts or Mathematics, in mentioning the game, teachers often referred students to me—'You should ask your CS teacher about the details as he is the expert.' I did feel the pressure.

As shown in the above teacher account, this special event along with the media coverage, had not only exposed students to AI topics, but educated them to some extent. The media exposure and peer discussions turned into a kind of informal learning for students. At another school with 180 Grade 5 primary school students, through a diagnostic assessment in the first lesson in September 2019, the CS teacher found that only 4.1% students had never heard about AI, 43.5% were confidently clear about what AI was, and 40.1% knew the general meaning of AI. Such informal learning out of classrooms indicated the changing population of primary students, who were born and grew up in media- and technology-rich environments. As students' daily lives were increasingly exposed to AI, they would naturally expect their teachers to help resolve confusions about AI-related topics.

The implicit and explicit student requests implied their new expectations on learning contents in the CS course, which meant both motivation and equal pressure for some teachers. The students' expectations especially echoed with the teachers' reflections on the existing CS curriculum. According to the teachers, "the existing course is dominated by obsolete content, such as how to turn on a desktop and use the office software; I would be surprised if students found such content interesting." They argued that to "update" or "keep up with the evolution of technology and respective skill requirement" was supposed to be a distinguishing feature of the CS subject and engineering/technology education, while the recent technological evolution had been largely ignored in the existing curriculum. As such, they were drawn to this AI curriculum project and regarded it as an opportunity "to cope with the crisis of Computer Science Education."

4.3.2 | Students as co-constructors of pedagogy

When students became a driving force for teacher engagement in the AI curriculum project, the teachers prioritized their interests and characteristics in the pedagogical design. For example, considering the characteristics of young learners, most teachers incorporated hands-on activities and gamification elements. One popular activity was the Human–Computer Competition, through which students competed with AI-empowered software in composing poems, recognizing hand-drawn sketches, completing missing parts in a photo, and other tasks. The inclusion of software and competition not only made the learning process fun and engaging but forged first-hand experimental opportunities. Meanwhile, digital and multimedia materials, such as Power Point Presentation (PPT) and animated videos, were widely adopted among the teachers, as sensorial stimuli to draw students' attention and as visual aids to facilitate student–content interactions.

The student-centered approach was also reflected in the teachers' efforts to build relevance for AI learning in the context of daily lives. Most teachers included real-life examples and cases in the teaching, to situate AI learning in students' everyday lives. This strategy was framed as "a solution to the cold start problem¹ in AI teaching," when the subject matter is new to the students who are barely primed to learn concrete concepts. The real-life examples could make the teaching/learning more tangible, while familiarizing the students with AI-relevant applications and broadening their horizons. In this way, the examples can provide an anchor for the students to make sense of and create meaning from their familiar experiences. In addition, the teachers also instructed the students to apply the knowledge to their daily lives, as a means to prepare their minds and craft their abilities in solving real-world problems.

On the other hand, it was by no means straightforward to select appropriate examples, as the teachers were fully aware of students' differences with respect to their life experiences and socioeconomic backgrounds. According to some teachers, such differences, if not gaps, could be salient, considering that AI-powered gadgets "are not affordable for every family." The teachers had to "be constantly reminded to be sensitive and careful" to avoid potential inequality. One strategy was "to find and frame examples from students' common experiences, such as the school life." For instance, one teacher exemplified the topic of image recognition with an automatic license-plate recognition system deployed at the school entrance. Such examples extracted from the public space were less likely to make any students feel disadvantaged. A similar strategy was to promote certain shared experiences within the class and build a common foundation to learn AI together, rather than overly relying on out-of-school experiences.

4.3.3 | Students as evaluators in the teacher-initiated curriculum

The vast attention paid to the students prompted their role as curriculum evaluators. Given the experimental nature of the teacher-initiated curriculum, there still lacked standardized assessments, which were often used in conventional subjects to establish and maintain accountability for student learning. Some teachers argued that the standardized assessment was not the only pathway to accountability, but rather the student learning experience, concerning how students felt and thought about the AI curriculum, equally mattered. Meanwhile, most of the teachers acknowledged that, though this curriculum was still premature and under development, positive feedback from students had greatly reassured them that "it was the right thing to do." One interviewed teacher elaborated that, "when students saw it as a rewarding learning experience, I genuinely felt fulfilled and confident. It made me realize that I am doing a meaningful project, and I should carry on." The students appeared to be more than learners or receivers of curriculum change, but also partners who supported the teacher through a time of uncertainty and self-doubt. In this regard, the students to some extent became a source of justification for the teachers' curriculum efforts and professional engagement.

5 | DISCUSSION

This ethnographic research examined a primary school AI curriculum with a focus on teachers' perspectives and responses in mediating external influences into local schools and classrooms. The research has identified three significant sources of external influences—policy orientation, university experts, and students' out-of-school life experiences. For each source, the teachers negotiated the situational logics and strategic actions in making sense and use of the external influence to address local challenges and needs in classrooms/schools. By uncovering teachers' agentic engagement in such a complex environment, the study also demonstrates the unique values of ethnographic observation and immersive engagement in approaching the increasingly complex curriculum environment in engineering education.

Using the AI curriculum as a telling case, the research addresses a pressing challenge in precollege engineering education caused by the trend of knowledge transition (Kelly et al., 2008). That is, technological advancement in tandem with the digitalization of human activities have created new sciences and fields of inquiry, hence disrupting the existing landscape of engineering disciplines. The K–12 teachers and schools, while having limited access to knowledge creation processes, are nevertheless placed at the forefront of managing consequential challenges—how we can educate and prepare the young generation of students for jobs, professions, and lifeworlds that are still in formation and transition. The research shows the potentials of teacher agency and teacher-initiated curriculum in developing grassroots solutions for addressing the transition. As teachers are equipped with knowledge of local students and communities, they could be provided with more space and supports to serve as a catalyst and focal point for change.

The research findings provide important implications for pre-college engineering education. First, the study offers evidence that complements the understanding of the interaction between teachers and education policies. Previous studies appeared to suggest dissonance or indifference in teachers' attitudes toward policies and policymaking, which they often regard as "official rhetoric" with minimal effect on classroom practices (e.g., Mittell & Penny, 1997; Tiwari et al., 2015). However, the present study shows that teachers with agency, while being sensitive to relevant policies, can strategically interpret and harness them in favor of their professional role, interest, and position. Their strategic actions suggest a need for involving teachers in policy-making processes, especially since teachers' resistance to changes has been a major hindrance to reforms (Bybee, 2013). The involvement of lead teachers, especially those who are actively and agentially engaged in grass-roots curriculum initiatives, can help communicate teachers' perspectives, thoughts,

and needs to the education authority and take into account the teachers' personal and professional considerations in educational planning and policymaking. By valuing the teachers' voice and seeking their inputs, policymakers are more likely to build trust with teachers, obtain their commitment to change, and eventually sustain the curriculum change.

Second, our research verifies the affordance of cross-sector collaboration, such as school-university or school-industry partnerships, as well as the contribution of external content experts, in enhancing teachers' professional capacity and teaching practices (Hamilton et al., 2021; Larkin et al., 2009). In particular, it orients our attention to the teachers' professional growth in epistemic understanding, which has been rarely discussed in precollege engineering education (Dai, 2022). Teachers' enhanced personal epistemology, along with their teaching practices, imply a need for more epistemology-related PD activities in engineering teacher education programs, such as research activities, lab visits, and guided reflection, where teachers can gain first-hand experiences of engineering inquiry and grasp the nature of engineering knowledge and knowing. The effort to enhance teachers' epistemology may pave an avenue to transform school culture and teaching practices from reproducing knowledge to constructing and creating knowledge.

Third, the research addresses a need to re-conceptualize the student and teacher-student relationship under the subtle but continuing impacts of technology advancement and societal change in the 21st century (Greenhow & Lewin, 2016; Pereira et al., 2019). Engineering and technology education appear to be the school discipline most influenced by the change. Students' exposure to and interaction with technologies are greatly expanded in the media- and technology-rich environment, which further penetrates the peer world and classroom life. Their use of technology further diversifies their life experiences and backgrounds, resulting in changed expectations on teaching and teacher responsibility. Meanwhile, the research leads to concerns on the socioeconomic gap among students, especially considering the enlarging wealth gap (Ball, 2021). Students' differentiated access to digital devices, especially those high-tech or AI-powered gadgets, can result in discrimination on those socially and economically disadvantaged students. It is necessary to join forces between the public and private sectors in fostering inclusive and accessible learning opportunities for all students.

The situated and contextual nature of the research findings echoes with the view on education change as a social, cultural process (Dimmock & Walker, 2005). To further warrant the findings, some additional social, cultural, and historical factors are provided for consideration. First, in addition to professional agency, the vast amount of efforts devoted by the primary CS teachers may also be attributed to the social, cultural environment. That means that, in the Chinese culture, education has long been regarded as a major, if not the most important, ladder of social mobility. School teaching, especially in public schools, is considered to be a prestigious and stable occupation. Without significant concerns about job security, they are more likely to dedicate themselves to long-term engagement in bottom-up curriculum initiatives with limited resources (Bao, 2002; Ouyang & Paprock, 2006). Second, the teachers' dissatisfaction with the marginalized status of CS education should be understood in the examination-oriented culture that is prevalent in East Asian societies (Kwok, 2004). Although CS curriculum has been included in the official curriculum framework, it is not required in the high-stake summative assessment, such as the secondary school admission examination. The lack of assessment requirements placed the CS subject in an unfavorable position. This was especially true on account of the curriculum overload that forced teachers of different subjects to compete for limited teaching time and resources. Third, the research was situated in the context of Metropolitan Beijing, which is one of the most developed regions in China, and where education resources are relatively abundant.

6 | CONCLUSION

This ethnographic study presents multifaceted and situated accounts about the process of *how* a group of primary teachers responded to a complex environment of external influences and local challenges while developing a new curriculum. In presenting the three sets of external influences (i.e., the orientation of state-level educational policies, AI faculty at a partner university, and students' media and technology environments), the study highlights the multifaceted negotiation involved in the collaborative curriculum development, as well as the significance of teacher agency in initiating and sustaining a curriculum change.

There are several limitations of this study. While it focused on the practice and process of curriculum development, it lacked a quantitative evaluation of the curriculum effectiveness and student development. In addition, given the research scope and theoretical framework of teacher agency, it focused on the teachers' perspective and experience through field observation and interviews. Even in analyzing the pedagogical design, limited details were provided concerning the micro-interaction between teachers and students enacted in classrooms.

With respect to future work, we will shift the research focus from the overall curriculum development to the teaching and learning process. Specifically, the research team has gained the data access from two primary schools to film classroom interactions and examine the meaning making and knowledge construction *in situ*. This micro-analysis will provide a foundation to scrutinize and evaluate whether and to what extent the curriculum/instruction design supports or constrains student development of AI literacy. Meanwhile, pre-test/post-test quasi-experimental research has been planned to robustly evaluate the effect of the focal curriculum on students' AI understanding and ethical sensitivity. Last but not least, we are particularly interested in educating and preparing the newest generation of learners about social and ethical challenges revolving around AI. To extend the existing pedagogical practices, we have collaborated with CS teachers from the two partnered schools to develop design-based research on pedagogical designs and learning facilitation regarding AI ethics.

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ENDNOTE

¹ Cold start problem is a technical problem about automated data modeling in computer-based information system, where the system cannot draw initial data or input for the data modeling and optimization at the beginning stage.

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