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A phenomenographic approach on teacher conceptions of teaching Artificial Intelligence (AI) in K-12 schools

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Abstract

Artificial intelligence (AI) education for K-12 students is an emerging necessity, owing to the rapid advancement and deployment of AI technologies. It is essential to take teachers' perspectives into account when creating ecologically valid AI education programmes for K-12 settings. However, very few studies investigated teacher perception of AI education. Phenomenography is an empirical research method that was widely used to understand teacher's interpretive understanding of new phenomenon, in this study, the teaching of AI in secondary school. Therefore, the present study investigated teachers' conceptions of teaching AI using a phenomenographic approach. Twenty-eight in-service teachers from 17 secondary schools in Hong Kong were invited to participate in an interview after implementing an AI curriculum. Six categories of teacher conceptions were identified: (1) technology bridging, (2) knowledge delivery, (3) interest stimulation, (4) ethics establishment, (5) capability cultivation, and (6) intellectual development. The hierarchical relationships of the six concepts were organised as an outcome space. The space shows a range of surface to deep conceptions and offers an understanding of how teachers perceive AI education through their teaching experience. Two learning paths have been suggested for cultivating technical and non-technical teachers for teaching AI. These learning paths provide insights for teacher educators and policymakers to enhance teachers' competence in teaching AI and promote general AI education for K-12 students.

Keywords Artificial Intelligence (AI) education · K-12 school education · Teacher conceptions · Phenomenography · Teacher professional development

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1 Introduction

Artificial intelligence (AI) refers to machines that demonstrates human intelligence to perform tasks and can iteratively improve themselves using the data they collected, and its application facilitate intelligent automation are increasingly used in our daily lives (Duan et al., 2019). Regarded as a key element of the fourth industrial revolution, substantial changes to education practices are also envisioned (Seldon & Abidoye, 2020). To stay competitive, learners need to acquire AI knowledge and skills to live and work in an AI-infused society (Chiu et al., 2022). K-12, from kindergarten to 12th grade, is an education level. In research and education context, this level, different from higher education, is seen as general education that provides all children with a set of fundamental knowledge essential for children pursue of higher or vocational education. While the importance of AI is well recognized in higher education with professional degree programmes, it is also important to arouse all students' interest for AI from an early age (Chiu et al., 2022; Delaine et al., 2016). As intelligent machines become ubiquitous, equipping all K-12 students with basic AI knowledge has emerged as an important global strategic move to educate the next generation (Chiu & Chai, 2020; Touretzky et la., 2019). Current studies on K-12 AI education have focused on identifying AI content knowledge, skills, and tools for effective student learning (Sabuncuoglu, 2020). These studies have provided essential information to academia, policymakers, and practitioners, particularly for the early stage (i.e., introduction of AI education). However, more studies are needed especially from teacher perspective. In particular, teachers' conceptions of teaching influence how well and efficiently an initiative can be implemented (Alt, 2018; Zhang & Liu, 2014). At the beginning stage of educating the young for an AI world, understanding how teachers conceive AI education could provide important insights for future teacher professional development (Desimone, 2009; Guskey, 2002).

Phenomenography is well acclaimed as a qualitative research method used to investigate learning and teaching conception in education (Åkerlind, 2008; Roberts, 2003). It is widely used to investigate issues in a new or poorly described field and it does not start with a solid conceptual framework (Larsson & Holmström, 2007; Marton & Pong, 2005). This method posits that individuals experience teaching and learning differently because experience is always relating to part of a phenomenon rather than the whole. Each individuals' experience can be contributed to the collective sum of a larger whole. This research method has been used to understanding teacher conception (Akerlind, 2008; Harris 2008; Prosser et al., 1994).

Drawing from phenomenography that examine individual's experience and understanding of a phenomenon (Åkerlind, 2008; Marton & Pong, 2005), teachers' conceptions could be classified into two broad categories: teacher-centered conceptions and student-centered conceptions (Chan & Elliott, 2004; Kember, 1997). The teacher-centered conceptions focus on teacher effort, and on content and assessment. In contrast, the student-centered conceptions are focused on facilitating student's deep understanding of the knowledge. Recent study clearly indicates that teachers' conception of teaching shapes the way they integrate technology for education (Chen et al., 2021). Hence, teachers' conceptions are associated with their competence and attitudes, and they can be changed through their teaching experiences and profes-

sional development activities (Kember, 1997). Teaching AI in K-12 schools is a new phenomenon, lacking of relevant studies. School teachers with different backgrounds see teaching AI differently. Therefore, this study aims to unpack the teachers' variation in the ways they experience and understand what they are engaged in (Larsson & Holmström, 2007); hence to describe and identify teachers' conceptions of teaching AI through a phenomenographic approach. The research questions in this study are as follows:

1. What are K-12 teachers' conceptions of teaching AI?
2. How do their conceptions relate to instructional approaches?

Accordingly, the findings of this study could contribute to AI Education development for four parties: teacher educators / researchers, governments, school leaders, and AI teachers. They suggest how to develop guidelines for designing and delivering teacher professional development activities, to establish standards for teacher AI competence, and to design school-based AI teaching units.

2 Literature Review

2.1 AI education for K-12

In K-12, AI is new and unfamiliar to teachers, educators, and researchers; currently, AI education is not well-researched. Moreover, recently published literature has focused on identifying AI content knowledge and learning outcomes. Their findings aim to provide guidelines for schools to design and deliver their own AI curricula. For instance, Touretzky et al., (2019) proposed five big ideas (perception, representation and reasoning, learning, natural interaction, and societal impact) as components for K-12 AI education. These ideas guide curriculum designers and policymakers in selecting relevant AI knowledge, skills, and attitudes to be included in the school curriculum. The formulation of these content areas promotes AI literacy in general, which Long & Magerko (2020) defined as "*a set of competencies that enables individuals to critically evaluate AI technologies; communicate and collaborate effectively with AI; and use AI as a tool online, at home, and in the workplace"* (p.598). Chiu and colleagues (2022) proposed three goals for AI education: (1) preparing young individuals for life with AI, (2) cultivating AI talents by fostering a deeper understanding of AI, and (3) training future professionals across different fields to integrate AI in their jobs ethically and safely. These works have helped establish the foci and directions of the AI curriculum to empower non-technical students.

In addition to curriculum guidelines, AI education projects have been launched in different regions to create learning resources to respond to this global initiative. The Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA) formed a joint working group to develop national guidelines for teaching K-12 students AI (Touretzky et al., 2019). In mainland China, a series of AI textbooks for schools, *Fundamentals of Artificial Intelligence*, emphasise the technical concepts of core concepts of AI and coding. Although

textbooks cover daily life applications, they better fit the needs of students with engineering backgrounds (Sensetime, 2018). In Hong Kong, AI for the Future (AI4future) uses a module-based and level-up design to create teaching and learning resources for junior secondary school students (Grades 7 to 9) (Chiu et al., 2022).

AI concepts and knowledge can be introduced to schools in other subjects such as mathematics, science, and liberal studies. For example, Sabuncuoglu (2020) designed one-year curriculum content to teach AI through integrating mathematics and science knowledge for secondary schools. The curriculum developed students' awareness of the human factors and ethics in AI design. In most curricula, AI ethics are an essential component (Borenstein & Howard, 2021). AI ethics education can foster a mindset for the next generation of AI developers, highlighting the risks of malicious applications in AI research (Payne, 2019; Siau & Wang, 2020). Overall, most current studies have focused on AI content and outcomes, with few studies focusing on teachers' perspectives. To prepare teachers to teach AI, Van Brummelen (2021) co-designed integrated AI curriculum content with non-computer science K-12 teachers through a two-day remote workshop to prepare teachers to teach AI. Teachers experienced how to integrate AI knowledge into non-computer science subjects. Chiu et al. (2022) also employed a co-design approach to creating an AI curriculum. Nonetheless, effective K-12 education is strongly associated with teachers' conceptions of teaching, and studies on teachers' conceptions are lacking.

2.2 Teachers' conceptions of teaching and AI education

Teachers' conceptions of teaching are viewed as instructional and pedagogical ideas about the nature of content knowledge, how to teach students, and how students learn (Alt, 2018; Kember, 1997; Chiu, 2022). These conceptions are associated with teachers' preferred ways of teaching and learning, such as the roles of teachers and students and the delivery of content (Chan & Elliott, 2004). They reflect teachers' understanding of content knowledge, pedagogical purposes, and student learning outcomes (Pratt, 1992; Vermunt & Vermetten, 2004). Therefore, they affect the quality of teaching and student learning outcomes (Taylor & Booth, 2015).

The conceptions of teaching are classified into two categories: teacher-centred and student-centred conceptions (Chan & Elliott, 2004; Kember, 1997). In teacher-centred conceptions, instruction is concerned with the quantity of knowledge students receive and reproduce. The instructional design focuses on knowledge transfer from teachers to students through drills and practice, recitation, and rote memorisation. Teachers are deliverers and sources of knowledge, while students are passive receivers. Alternatively, student-centred instruction emphasises students' higher-order thinking skills. It treats learning as knowledge construction and focuses on teachers' efforts towards facilitating students' sense-making. Teachers oriented by student-centred conceptions create learning environments that foster students' sense-making. Through interactive and collaborative activities, students foster creativity and critical thinking skills (Cheng et al., 2009). They can express their ideas based on prior knowledge and construct their understanding (Brady, 2004; Woolfolk, 2012).

Emerging studies on teachers' conceptions of teaching in technological environments indicate that teachers' conceptions lie between the teacher-centred knowledge

delivery and student-centred knowledge construction continuum (Chen et al., 2021; Hsieh & Tsai, 2017), referencing technology and the subject matter being taught. Highly sophisticated teaching concepts are associated with a more refined use of technology. For example, Chen et al., (2021) discovered that Chinese language teachers who intend to build the students' writer identity used virtual reality to connect students affectively to the sociocultural environment rather than just a means to raise examination performance. In the case of AI education, how teachers conceive of teaching this new technological knowledge should be mapped out to represent possible teachers' professional development trajectories. This helps researchers understand teachers' perspectives and facilitates teacher development. Variation in teachers' conceptions of AI education reveal their strengths and weaknesses in teaching AI, provide insights for teacher educators and policymakers on enhancing AI competence, and promote general AI education.

3 Method

3.1 Setting, participants and sampling

This paper reports findings related to teacher development efforts in a project called "AI for the Future" (https://cuhkjc-aiforfuture.hk). It aimed to develop and establish a sustainable AI education model for Grades 7 to 9 students. An AI curriculum was co-designed by professors from the Faculties of Engineering and Education, secondary school teachers. The project's learning outcomes have been significantly positive in promoting students' AI literacy and self-efficacy (Chiu et al., 2022).

The participants included 28 teachers from 17 schools. The schools were purposefully selected from different districts of Hong Kong with varied social and economic characteristics, including girls', boys', and coeducational schools with different overall academic standards. This sampling method aims to cover different characteristics schools of a population. To make sure all the teacher participants have experience in AI education, all the teacher participants participated in co-designing one of the first AI curriculum for Hong Kong secondary schools. They had taught at least one AI-related topic in their schools (e.g., visual recognition), which lasted three to four weeks; Table 1 presents their demographic characteristics. Twenty-three participants (82.1%) were men. Nine (32.1%) graduated from Information Technology (IT)/Information Communication and Technology (ICT) or ICT in education, and six (21.4%) graduated from computer science. The other 13 teachers graduated from faculties such as engineering (four teachers), mathematics (three teachers), science or chemistry (three teachers), information systems (one teacher), physical education (one teacher), and sociology (one teacher). Fourteen teachers had over ten years of teaching experience, but twenty-seven of them had 1–2 years of teaching experience in AI. T1 to T10 joined the project for two years and co-designed the AI curriculum with engineering and education professors in the project's first year. T11 to T28 participated in the project in the second year and attended a 3-day comprehensive teacher programme before implementing the curriculum.

3.2 Data Collection

After obtaining consent from the participants and their schools, we interviewed them individually through ZOOM. The average duration of the interviews was 40 min. All interviews were audiotaped using verbatim transcriptions. Interview protocols were adapted from Chen & Tsai (2021) and Hsieh & Tsai (2017). The following are some key questions:

- In your opinion, what is the role of AI education in secondary school education?
- How would you describe your experience of teaching AI to secondary students?
- Please describe an AI lesson in your classroom that you deemed successful/unsuccessful.
- How do your students learn from the AI lessons?
- If you were to provide a formal definition of "AI education," how would you phrase it?

3.3 Data Analysis

The phenomenographic approach (Marton & Pong, 2005) was adapted to identify teachers' conceptions of teaching AI through their teaching experiences. The approach aims to "reveal the qualitatively different ways of experiencing various phenomena" (Marton & Booth, 1997, p. 136) to understand human actions within society (Sandbergh, 1997). Phenomenographic outcomes are generally presented as categories of description and outcome space. Conceptions refer to "whole qualities of human-world relations" at the individual level, whereas categories of description are at the collective level, even though they are used to denote conceptions (Marton & Booth, 1997; Sandbergh, 1997). The outcome space acts as "synonym for phenomenon" that describe "the logically structured complex of the different ways of experiences of an object" (Marton & Pong, 2005, p. 105). Knowledge of the outcome space may provide insights for educators to support changing and growing teachers' conceptions (Stein et al., 2011).

The data was analysed by a postdoctoral fellow who has expertise in STEM education, and two experienced scholars – assistant and full professors - with expertise in technology education and teacher education in K-12. The interview transcripts were analysed in an iterative process, as described by Marton & Pong (2005). The transcripts were examined using the outcome space discussed earlier several times to identify and develop initial ideas regarding teachers' conceptions of AI teaching by the postdoctoral fellow and the assistant professor manually. The full professor acted as a moderator to make decisions on the disagreements. During this process, significant keywords and sentences were extracted. The similarities and discrepancies of the extracted data were then compared to develop different categories of descriptions based on the structural relationship of teachers' conceptions. Refinement of description categories through the iterative process of moving transcripts and drafts of description categories were conducted to address inconsistencies between transcripts and categories. Thus, the final descriptions categories capture the critical variation between different ways of experiencing across the collective experiences of

Table 1 The demographic background of the participants

Teacher	Gender	Education qualification	Subject	Teaching experience (in years)	Teaching experience in AI (in years)	Teaching subject
T1	M	Bachelor	Engineering	22	5	ICT
T2	M	Master	Computer Science	16	2	ICT
T3	M	Bachelor	ICT in Education	20	1	ICT, Mathematics
T4	F	Bachelor	ICT in Education	2	2	ICT
T5	M	Master	ICT in Education	6	2	ICT, Mathematics
T6	M	Master	ICT in Education	10	1	ICT
T7	M	Master	Chemistry	6	2	Science, ICT
T8	M	Master	Chemistry	20	2	Science, ICT
T9	M	Master	Computer Science	3	2	ICT
T10	M	Master	IT with Business Management	3	2	ICT
T11	F	Bachelor	Computer Science	1	1	ICT, Mathematics
T12	M	Master	Information System	20	2	ICT
T13	M	Bachelor	ICT in Education	20	2	ICT
T14	F	Bachelor	ICT in Education	1	1	ICT, Mathematics
T15	M	Master	Engineering	13	1	Science
T16	M	Bachelor	Physical Education	11	1	ICT, Mathematics
T17	M	Master	ICT in Education	30	1	ICT
T18	M	Bachelor	Computer Science	8	1	Science
T19	M	Master	ICT	5	1	IT
T20	F	Bachelor	Engineering	20	1	Mathematics, ICT
T21	M	Master	Sociology	1	1	ICT, Mathematics
T22	M	Master	Engineering	20	1	ICT
T23	M	Bachelor	Computer Science	26	1	ICT
T24	M	Bachelor	Mathematics	5	2	Mathematics, ICT
T25	M	Bachelor	Mathematics	1	1	Mathematics
T26	M	Bachelor	Computer Science	4	1	ICT
T27	M	Master	Mathematics	33	1	ICT, Mathematics
T28	F	Bachelor	Science	13	1	ICT

all transcripts. Finally, the researchers constructed a hierarchical structure of teachers' conceptions of teaching AI. Each category was described with key features, and an outcome space was generated to connect the description categories.

Table 2 The six categories of teachers' conceptions of AI education

Features	Category 1 Technology Bridging	Category 2 Knowledge Delivery	Category 3 Interest Stimulation	Category 4 Ethical Consideration	Category 5 Capacity Cultivation	Category 6 Intellectual Development
Teaching objectives	Bridging AI and real world	Knowledge transfer from teacher to student	Stimulating students' interests in AI	Establish students' AI ethics	Competence building	Practicing problem-solving and design thinking
Instructional methods	Association with AI applications as bridges	School-based instructional practice	Interactive learning activities	Learning reflection	Interaction with intelligent machine	Project-based learning
Student learning outcomes	Increased awareness of AI	Accumulation of knowledge and skills	Active engagement in AI lessons	Realising the ethics issues when using AI	Transferrable knowledge	Intrinsically motivated to learn AI

4 Results

4.1 What are K-12 Teachers' conceptions of teaching AI?

Six categories of teachers' conceptions were identified throughout the analysis: (1) technology bridging, (2) knowledge delivery, (3) interest stimulation, (4) ethics consideration, (5) capability cultivation, and (6) intellectual development. Table 2 shows the six categories of teachers' conceptions, with three key features: (1) teaching objectives, (2) instructional methods, and (3) student learning outcomes.

4.1.1 Category 1: Technology Bridging

In this category, the teachers described teaching AI as a means of raising students' awareness of AI applications in daily life. The teaching objective was to help students identify the AI technologies surrounding them. The concepts and theories underlying AI technologies were excluded at this stage. The excerpts from the teachers are as follows:

> *Just to let them be aware of how AI relates to their daily lives (T1)*
> *AI is no longer far from students; it has been invented and is around them. (T5)*

Different types of AI applications have been used to provide students with references to teaching. Using real-life AI applications helps students notice AI's pervasiveness and importance. Concrete AI applications assist students in grasping how AI works and motivate them to learn it.

> *We used auto-driving cars (as an example in the lessons), and students realised that AI technologies were not out of reach. This could have raised their awareness. (T20)*
> *Maybe let them know what face ID or facial recognition can be applied in the working environment and how people use it in daily life. (T11)*

The teachers observed an increased awareness of AI technologies among their students in real-life situations that matched their learning objectives. Students can identify AI technologies in their daily lives.

Minimally, I think they have increased their awareness, that is, they started to pay attention to AI in their daily lives, such as Siri, and why there are some suggested pages and advertisements that popped up on Facebook. This was related to their daily experience. (T26)
They started to pay more attention to it, realising what is considered AI. (T18)

4.1.2 Category 2: knowledge delivery

In this category, the teachers believe that teaching AI is a process of knowledge transfer from teachers to students. They delivered AI knowledge and skills to educate students on acquiring knowledge and skills. The following excerpts illustrate this:

I think it is necessary to understand some AI-related concepts at the junior secondary school stage. (T15)
We also included the knowledge part; we hope that the students will know some underlying working principles. (T22)

The AI curriculum designed by professors and school teachers (Chiu et al., 2022) forms a fundamental framework for AI education in their teaching. Teachers adopted school-based instructional practices by customising the given curriculum. They transformed abstract AI concepts with metaphors or built knowledge by connecting the concepts of AI. The refined instructional practice matched the students' competence and facilitated their learning.

When teaching the concept of a classifier in computer vision, we used cards with different pictures, such as emojis. Students were asked to group the pictures and state their reasons. They can learn the basic idea of how a computer classifies pictures (data). (T8)
First, we introduce the basic concepts of AI. We then connect these concepts to AI reasoning. There are three levels of AI reasoning: skill-based, rule-based, and knowledge-based. If a technology has the first two types of reasoning, it is not AI. If it has knowledge-based reasoning, then it is AI technology. (T10)

The teachers provided the selected knowledge. They reported that students could comprehend the basic concepts and terminologies behind AI applications through in-class activities and chapter-end assessment exercises.

They obtained a clear picture of the working principle of the application. (T15)
We found that the scores of the chapter-ended assessment exercises were not low in general, and their responses in the class reflected that they could master the knowledge; they knew what they had learned. (T10)

4.1.3 Category 3: interest stimulation

In this category, the teachers regarded teaching AI as a means of stimulating students' interest in AI and inspiring them to pursue AI-related careers. The following two excerpts show the teachers' responses:

> *When more outstanding students have developed their interests (in AI), they can continue to do so towards that direction. (T12)*
> *Not only can they know more about AI but also to arouse their interests, so I think it helps with their personal development, or even learning interests and learning motivation. (T10)*

Interactive learning activities, such as classroom discussions between teachers and students and hands-on activities with AI applications, were strategies to motivate students to explore AI topics.

> *Apart from direct teaching, we also consider other teaching methods, such as lesson activities and discussion in lessons. (T17)*
> *I let them analyse what should and should not be an AI, and I also let them share their thoughts and feelings. (T11)*

The teachers observed that their students demonstrated an interest in AI-related topics. Student engagement increased, reflecting students' interest in the discussions. Some students showed an interest in pursuing AI in future studies.

> *When discussing an example of AI auto-drive, students were interested in the topic and were eager to know and share. (T17)*
> *We have AI summer courses, and enrolment is full. Students are eager to learn AI beyond formal classes. (T28)*

4.1.4 Category 4: Ethics Establishment

> The misuse, abuse, or poor design of AI systems may cause potential harm to society. The teachers were acutely aware of such concerns and considered teaching AI a vehicle for building students' AI ethics. The typical excerpts are shown below.
> *I think they (students) should know how AI benefits society and how we use them properly; it is an important part. (T14)*
> *We have many topics about AI ethics; they should know the ideas so as to make decisions on whether or not to use AI. (T26)*

Teacher-led discussions with real-life scenarios offer students opportunities to reflect on associated ethical issues. This discussion helps students consider the potential threats of AI that violate ethical principles.

I hope the students know how to decide whether they use or do not use AI after learning. (T10)
We will raise some questions to reflect such as "If you are identified by face ID, do you like it?" (T23)

The teachers found that their students were conscious of the ethical uses of AI technologies. Integrating AI ethical issues in discussions encourages students to use and develop AI technologies more wisely.

When discussing ethical issues, they would know that they also relate to themselves. (T5)
When they use computer vision with AI, they know how to protect their privacy, at least they know how to judge whether the policy is good. (T17)

4.1.5 Category 5: capability cultivation

With a strong awareness that AI technologies are increasingly infused in the workplace, the teachers regarded teaching AI as building students' capabilities to cope with AI through coding or interacting with intelligent machine operations. They believed that hands-on practices would increase students' competitiveness for human-machine collaboration in the future, as exemplified by the following:

AI has been infused into the scope of their future work. (T8)
AI is something that we have been using and will be used in the future. If we learn coding right now, I can say it must be applied in the future; it must be a developmental direction. (T27)

Teachers believed that hands-on experiments are essential for students to apply their knowledge to real-life situations (Admane & Mondhe, 2021).

Additionally, we must arrange hands-on activities for them. This year, we mainly used a teachable machine to allow them to experience online. (T24)
We would like to add that we would try to provide experiments for every chapter and every topic. (T10)

The teachers found that their students started to understand how perception could be achieved through "doing" the practical tasks. The success of integrating knowledge such as physical features of things and sounds with how machines learn enriched students' understanding of abstract AI concepts.

For example, there are different features in recognising the pictures, such as how many legs, how long the ears, and a lot of data. At least they know these concepts, it is like why the machine can recognise dogs as dogs instead of cats. (T23)

They understood more about voice recognition and image classification, so when they were working on a teachable machine, they could discover the problems immediately. (T3)

4.1.6 Category 6: Intellectual Development

In this category, teaching AI can inspire students to design AI models and extend their study to AI in the future. Students can integrate AI knowledge and transform AI products. The following excerpts show this:

Perhaps when they think of their design or strategies, they may create new products by considering those elements. (T3)
Creating products that can solve daily real-life problems. This is what we want to see the most. (T6)

Nurturing creative and innovative thinking is a key skill required in the AI industry. Ten teachers adopted the project-based learning approach to allow students to apply their knowledge and skills when designing AI products.

We eventually had an AI-enabled robot... they really had to think and design a programme. (T21)
The students designed an AI programme to help the blind. It can identify the objects, the position, and the distance of an obstacle, and produce sounds to alter the potential dangers, such as hitting the obstacle. (T9)

The teachers reported the students' ability to learn extensive AI knowledge. The students executed and refined their innovative ideas, AI knowledge, and practical skills through extracurricular activities. The teachers observed some indicators of design thinking. For instance, some students with keen interest have attempted to create games and platforms through self-initiated learning of programming languages beyond the curriculum. Students' intrinsic motivation and lifelong learning were promoted.

Many students asked me whether there would be some AI activities and competitions that they could join, which is how we make students truly apply their skills to another level. (T17)
He wrote it (program) himself, like a game for others to play. I also discovered that he started to create a platform; he also tried to learn C++ by himself; I just let him do what he wanted. (T9)

4.2 Distribution of the Teachers' conceptions

Table 3 illustrates the distribution of teachers' conceptions across categories based on their reported experiences. The number of times that the teachers stated a cer-

tain idea and were converted into symbols and identified into "general," "main," and "achieved" conceptions. The general conception (✓), which refers to a teacher's conception, was identified in a category. The main conception (★) denoted the central idea, that is, the highest frequency expressed in each teacher's interview. The achieved conception (※) designated the highest-level category mentioned by teachers. For instance, T28 had 35 general conceptions regarding teaching AI that spread across all six categories. The most frequently mentioned conception was Category 3 (10 counts). Thus, his main conception category was Category 3, but his highest achieved conception was Category 6. Nearly all teachers expressed their conceptions of Category 1 (n=27) and Category 2 (n=27), but only 16 and 18 teachers showed their ideas with the conceptions of Categories 6 and 4, respectively. Categories 1 (n=9) and 2 (n=13) were the most frequently reported conceptions of teachers. Regarding the achieved conception, all teachers reached either Category 5 (n=12) or 6 (n=16). Although teachers might believe that mastering knowledge and skills were the foundation of students' learning at the junior secondary school level, some teachers extended their expectations to cultivate their students to pursue AI-related education in the future.

As the teachers had different experiences in participating in and implementing the AI curriculum, we further compared the distribution of their conceptions. Year 1 teachers (T1 to T10) had two years of experience co-designing the AI curriculum with professors in the project's first year. They had two years of experience implementing the curriculum. In contrast, Year 2 teachers (T11 to T28) were trained but participated in the project in the second year, attending a 3-day comprehensive teacher training and had only 1-year of teaching experience in the curriculum. A chi-square test of independence was performed to examine the relationship between the level of conceptions achieved and the years of joining the project. The relationship between the two variables was not statistically significant (c^2 (1, N=28)=0.052, p=0.820). Since we had 28 teachers, the identified conceptions might not be sensitive enough to detect the differences. The teachers had diverse educational backgrounds and teaching experiences. Thus, year 2 teachers could also have well-developed conceptions of teaching AI because they have well-developed conceptions of teaching their subject matter. Thus, AI, as a subfield of technology education, did not perturb existing conceptions. In addition, teachers have only taught several topics at most due to the limited time devoted to technology education. A good differentiation of conceptions among teachers might take longer to exhibit.

4.3 How do the Conceptions relate to Instructional Approaches?

Relationships among categories with hierarchical structures were established by comparing and contrasting their similarities and differences (Marton & Pong, 2005). Table 4 shows the outcome space with reference and structural components to illustrate this relationship. The referential components represent the "what" of teachers' conceptions, that is, the six categories of descriptions. The structural components showed the "how" of teachers' conceptions and emerged into three main dimensions, namely, (1) instructional strategy, (2) conceptions' domain, and (3) teacher intention.

The instructional strategy regards the teaching approaches as directed by the teacher or students, either teacher-centred or student-centred, or an intermediate of teacher-student interaction. The concept domain refers to the nature of the concepts: knowledge, attitude, or competence. Teaching intention is related to teaching objectives. The three dimensions demonstrate the six teachers' conceptions of teaching AI, ranging from surface to deep conceptions. Categories 1 and 2 are knowledge domains that aim to transfer knowledge using teacher-centred lectures as the main instructional approach. Categories 3 and 4 emphasise personal development in the attitude domain. Teacher-student interaction provides the means for students to reflect on themselves. Finally, the competence domain in Categories 5 and 6 offers the integration of knowledge and skills into life and work. It empowers students' continuous learning, driving the instructional strategy toward a student-centred approach.

5 Discussions

5.1 Empirical implications: Teachers' conceptions of teaching AI

This phenomenographic study proposes a variation in teachers' conceptions of teaching AI. These conceptions offer an understanding of teachers' beliefs about teaching AI that guided their classroom practice and influenced students' learning. In this study, six categories of teachers' conceptions were identified. Each category had three key features: (1) teacher objectives, (2) teaching methods, and (3) learning outcomes. An outcome space showing the relationships between the categories was presented in a hierarchical structure with three dimensions: (1) instructional strategy, (2) conception domain, and (3) teaching intention. The space showed a range from surface to deep conceptions and offered an understanding of how teachers perceive AI education through their experiences. In general, while the subject matter of AI is new, the associated conceptions of teaching are congruent with recent studies on teachers' conceptions of teaching with technologies (Chen et al., 2021; Hsieh & Tsai, 2017). The new variation seems to be along the deep conceptions, especially for coding intelligent machine behaviours and lifelong learning of AI. It seems clear that these conceptions were grounded in the essence of AI as an intelligent machine and the concern that AI technologies are just beginning to change the workplace with many potential disruptions. Thus, this study enriches the conception of the teaching framework to encompass AI teaching.

The variation in categories with hierarchical relationships indicated the goals of teaching AI at different levels. In Categories 1 and 2, the teachers considered teaching AI as new knowledge that students needed to acquire. Thus, the teaching intention was assimilated as the traditional transfer of information or knowledge to students. In addition to being end-users of AI applications, students should be aware of AI technologies (e.g., identifying AI real-life applications) and understand the knowledge behind the technologies (e.g., definition of AI) (Chiu, 2021Chiu et al., 2022; Touretzky et al., 2019). These teaching objectives are consistent with "recognising AI" and "understanding intelligence," the first two competencies of AI literacy proposed by (Long & Magerko, 2020). Without a technical background, public percep-

tions of AI are often regarded as synonymous with robotics (Fast & Horvitz, 2017) or the fallacy of superhuman AI (Mitchell, 2021). Thus, awareness and fundamental knowledge of AI are essential for students to develop their basic knowledge. In our study, 26 out of 28 (92.9%) teachers had two basic conceptions, and the other two teachers mentioned one conception. Developing students' conceptual understanding of basic AI knowledge is the core goal of AI education.

The conception domain extends beyond the knowledge domain to encompass the attitude domain in Categories 3 and 4. In these two categories, teachers focus on developing students' personal growth; 25 out of 28 (89.3%) teachers were concerned about students' interest in learning about AI. The teachers regarded cultivating interest as necessary; if students are interested in learning, their attitude towards learning is good, and they will be more engaged in the lessons (Kurniawan et al., 2019). Classroom discussion offers students the opportunity to reflect on their thoughts and feelings about AI topics. With the rapid deployment and widespread societal impact of AI, there is deep concern towards ethical considerations. The AI curriculum was designed with an explicit section on ethical issues (Chiu et al., 2022). It seems that the teachers were receptive and concerned with ethical aspects (18 out of 28, 64.8%). The results indicated that they had a general conception of AI ethics, although the conception was not as strong as the development of AI knowledge and AI competence.

Finally, the teachers reported sophisticated conceptions of the competence domain in Categories 5 and 6. The teachers regarded teaching AI as developing students' AI-related competencies and skills and cultivating AI talent. They believed that students could develop AI-related competencies by interacting with intelligent machines. Hands-on problem-based approaches contribute to high student engagement and inspire their 21st -century skills such as creativity and critical thinking that may extend their learning and pursue AI-related careers. In our study, 92.9% (26 out of 28) and 57.1% (16 out of 28) of teachers expressed the two highest levels of conceptions, respectively. Thus, teachers recognised that hands-on coding practices were essential for students to transform their knowledge into practical solutions. In technology education, design and problem-solving activities allow students to practice solving real-life problems by applying creative, critical thinking, design thinking, and problem-solving skills (Code et al., 2020; Shin, 2021). Project-based learning allows students to apply or design their own AI models, even though they may sometimes require sophisticated algorithms beyond their capabilities at secondary school levels (Chang & Tsai, 2021). Further, teachers' competence in AI knowledge and pedagogy is crucial for facilitating students' learning and cultivating their AI talents. Overall, the teachers' conceptions matched the goals of the AI curriculum (Chiu & Chai, 2020), indicating that teaching experience positively impacts teachers' professional development in teaching AI.

5.2 Practical suggestions: Professional Development activities for AI education

The deficiency of qualified and certified teachers in teaching AI has been a major hurdle in implementing AI education (Vazhayil et al., 2019; Xia & Zheng, 2020). Most teachers who would have been teaching AI did not receive formal education during their studies (Chiu & Chai, 2020). Teachers' knowledge gaps regarding AI may cause

Table 3 Distribution of teachers' general, main, and achieved conceptions of teaching AI

Teacher	Category 1 Technology Bridging	Category 2 Knowledge Delivery	Category 3 Interest Stimulation	Category 4. Ethics Establishment	Category 5 Capability Cultivation	Category 6 Intellectual Development
T1	4✓	11✓★	6 ✓	1✓	8 ✓※	0
T2	2✓	4✓	3 ✓	0	5 ✓★※	0
T3	4✓	6✓★	5 ✓	1✓	4 ✓	6✓★※
T4	1✓	1✓	3 ✓★	1✓	1 ✓※	0
T5	6✓	8✓★	8 ✓★	4✓	3 ✓	4✓※
T6	7✓★	5✓	2 ✓	4✓	1 ✓	3✓※
T7	1✓	0	0	1✓	3 ✓	4✓★※
T8	2✓	7✓★	6 ✓	0	0 ✓	5✓※
T9	5✓	4✓	3 ✓	0	5 ✓	6✓★※
T10	4✓	7✓★	5 ✓	1✓	4 ✓※	0
T11	5✓	6✓★	2 ✓	4✓	4 ✓	1✓※
T12	6✓★	6✓★	3 ✓	0	2 ✓	1✓※
T13	2✓	3✓★	2 ✓	3✓★	0	1✓※
T14	3✓★	1✓	2 ✓	3✓★	2 ✓※	0
T15	3✓	5✓★	0	0	1 ✓※	0
T16	6✓★	6✓★	2 ✓	0	5 ✓※	0
T17	2✓	5✓★	1 ✓	3✓	4 ✓※	0
T18	4✓★	2✓	3 ✓	0	0	1✓※
T19	6✓	5✓	7 ✓★	0	6 ✓	3✓※
T20	6✓★	1✓	1 ✓	3✓	1 ✓※	0
T21	1✓	1✓	0	1✓	1 ✓	2✓★※
T22	4✓	5✓★	2 ✓	3✓	2 ✓	1✓※
T23	6✓★	4✓	3 ✓	1✓	4 ✓※	0
T24	0	3✓★	4 ✓	0	2 ✓※	0
T25	3✓★	2✓	1 ✓	0	0	1✓※
T26	4✓★	3✓	1 ✓	2✓	1 ✓※	0

Table 3 (continued)

Teacher	Category 1 Technology Bridging	Category 2 Knowledge Delivery	Category 3 Interest Stimulation	Category 4. Ethics Establishment	Category 5 Capability Cultivation	Category 6 Intellectual Development
T27	2✓	4✓	6 ✓★	1✓	0	2✓※
T28	4✓	4✓	10 ✓★	2✓	9 ✓	6✓※
Total	✓ = 27 ★ = 9 ※ = 0	✓ = 27 ★ = 13 ※ = 0	✓ = 25 ★ = 5 ※ = 0	✓ = 18 ★ = 2 ※ = 0	✓ = 23 ★ = 1 ※ = 12	✓ = 16 ★ = 4 ※ = 16

Table 4 The outcome space

		Referential ("what" of AI education)					
		Category 1 Technology Bridging	Category 2 Knowledge Delivery	Category 3 Interest Stimulation	Category 4 Ethics Establishment	Category 5 Capability Cultivation	Category 6 Intellectual Development
Structural ("how" of AI education)	Instructional setting	Teacher-centred approach	Teacher-centred approach	Teacher-student interaction	Teacher-student interaction	Student-centred approach	Student-centred approach
	Conception's domain	Knowledge domain	Knowledge domain	Attitude domain	Attitude domain	Competence domain	Competence domain
	Teaching intention	Transfer of information	Transfer of knowledge	Development of personal interests	Development of personal ethics	Empowering students in practical uses	Empowering students for extended learning

misconceptions and hinder their classroom practice and curriculum designs. Accurate identification and description of teachers' knowledge gaps can guide effective professional development. Lindner & Berges (2020) found that teachers' pre-concept in AI contained fundamental concepts and ideas without concrete and in-depth descriptions. The explanation of AI applications mostly originates from their computer science background. Moreover, the current teacher training model for AI education is mainly to provide teachers with basic AI knowledge and practice (Xia & Zheng, 2020) or to implement certain prepared materials or curricula with teacher guides in their teaching (Williams et al., 2021). These studies reported that the participating teachers gained knowledge and experience through participation, but the short-term programmes may not cover a broad range of AI knowledge. Lindner (2021) initiated a professional development programme and identified basic teacher competencies. AI teachers should develop a profound knowledge of AI concepts, basic algorithms, terms and critically reflect AI ethical and social consequences (Borenstein & Howard, 2021).

However, AI should be introduced to schools in technical and non-technical domains. In this study, the six categories of teachers' conceptions and their relationships echo the interdisciplinary nature of AI and guide the design of professional development for all teachers, including technical and non-technical teachers. We used two major findings to suggest a learning path for all the AI teachers. There are two levels in this learning path. The first level concerns AI knowledge and pedagogy enhancement, whereas the second level concerns AI integrative learning. This learning path provides information to teacher educators and policymakers to design and deliver professional development activities for AI education.

Table 2 lists the learning paths for the first level. This path, which consists of three stages, is suggested for in-service teachers without a technical background and pre-service teachers. Stage 1 should include the teaching objectives, instructional methods, and student learning outcomes identified in Categories 1 and 2. At this stage, both technical and non-technical teachers will acquire knowledge for teaching AI. This stage provides foundational knowledge of AI, which is crucial for teachers'

professional development. In Stage 2, teachers should learn AI relevance to young children, such as ethical issues, societal impact, and future work (Chiu et al., 2022; Chiu, 2021). This relevance raises student interest and motivation to learn AI and highlights the importance of including AI in K-12 education. This stage is essential for both technical and non-technical teachers. The final stage is for technical teachers. Teachers should also learn how to facilitate students in creating or designing AI applications.

The second level emphasises enhancing more experienced teachers and curriculum designers. We suggest using the outcome space presented in Table 4 for professional development activities at this level. This space presents an overview of all six categories and how they relate to each other. The teachers and designers who finish this stage could integrate AI into different subjects by considering the entire school curriculum. For example, students can achieve the learning outcomes proposed (1) in Categories 1 and 2 by attending lectures from different subjects with less limited interaction sections (e.g., application of AI in different subject domains), (2) in Categories 3 and 4 by trying and experiencing different AI applications in different subject lessons; and (3) in Categories 5 and 6 by designing and developing AI applications for real-life problems using an enquiry approach. They should be able to use what they have learned from this stage to design holistic AI education for their schools while considering the needs of schools and students. In general, our findings of teachers' conceptions of teaching contribute to teacher training from teachers' perspectives.

5.3 Overall research contributions

Other than giving practical suggestions for teacher professional development, the findings of this study contribute to AI K-12 Education development for 4 different parties: teacher educators / researchers, governments, school leaders and AI teachers. These contributions would better train our teachers to be more competent in designing and teaching AI, and assessing their own teaching, which nurture more AI talents for the future. First, teacher educators / researchers could use the suggested outcome space, and technological, pedagogical, and content knowledge to (i) propose new models for AI teaching and learning, and to (ii) re-design their teacher education programmes to better foster pre- and in- service teachers AI disciplinary and pedagogical knowledge. Second, governments could use the outcome space to develop AI education policy by proposing a new standard for teacher AI competence / literacy, and developing AI curriculum including guidelines, pedagogy, and assessment. Third, school leaders could use the outcome space to consider (i) criteria to recruit new AI teachers and identify potential teachers within schools to teach AI curriculum, and (ii) guidelines to select relevant courses to fit their teachers' needs in term of pedagogical, and disciplinary knowledge. Finally, current AI teachers could use the outcome space to develop their own school-based curriculum: learning outcomes, teaching materials, instructional design, student learning approach and assessment. The teachers also could use the outcome space to self-reflect their teaching materials and approaches, and AI knowledge for improvement and professional development. They could also use the space as six dimensions (more systematic) to organize shar-

ing for their teaching with other peers within and between schools, rather than random sharing. For example, What have I done in "Category 1: Technology Bridging" and "Category 6: Intellectual Development" when teaching AI?

6 Limitation and conclusion

Teachers' perspectives are essential for curriculum development, as they are the end-users of curriculum materials (Chiu, 2017, 2021). With the growing demand for AI education for K-12 and the deficiency of competent teachers to teach AI, teacher training is important for ensuring good quality of teaching and learning. This study revealed six categories of teachers' conceptions of AI education and the hierarchical relationships among the categories. The findings highlight important elements of AI education from teachers' perspectives. These concepts play a crucial role in informing teachers' design and implementation of AI programmes in their classrooms and offer insights for teacher educators, schools, and curriculum developers to promote AI teacher education for K-12.

This study had three limitations. First, the findings of this study are mainly based on interview data from teachers. As such, there may be a certain inconsistency between teachers' discourses and their actual teaching practices. Teacher practice may vary according to their educational backgrounds and environments. Therefore, additional studies using objective measures, such as lesson observations and documents (e.g., worksheets), should be conducted to validate these findings. Second, most participants had a Science, Technology, Engineering, and Mathematics (STEM) academic background. The present results can be extended by additional studies using the perspectives of non-STEM teachers. Third, this study adopted a phenomenographic approach to study teacher conceptions because AI education for K-12 is a new field. After a few years, further studies should adopt other research designs with a more solid conceptual framework to develop curriculum guidelines from the perspective of teachers' conceptions.

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Statement on Open Data, Ethics, and Conflicts of interests

Data without participant identification in this study can be obtained by emailing the corresponding author.

The Survey and Behavioural Ethics Committee at the Chinese University of Hong Kong approved the study before data collection.

There is no potential conflict of interest in this study.

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