

# Artificial intelligence literacy in primary education: An arts-based approach to overcoming age and gender barriers

Iris Heung Yue Yim<sup>\*</sup>

Faculty of Education, University of Cambridge, Cambridge, United Kingdom

## ARTICLE INFO

### Keywords:

Artificial intelligence  
AI literacy education  
AI thinking  
Primary school students  
Arts-based pedagogy  
Age and gender difference

## ABSTRACT

Artificial Intelligence (AI) literacy education was previously taught primarily at the university and secondary school levels but has recently started to be expanded to primary school settings. When available at the primary school level, AI literacy is often taught within computer science courses, which may potentially reinforce gender stereotypes and discourage female students' engagement. In AI literacy education, the predominant teaching methods are constructivist approaches, which, while effective in fostering active learning, heavily emphasize technical skills and are therefore limited in their pedagogical scope, as they underplay other important questions, such as disinformation, data justice, and AI's ethical and societal implications. The lack of a clear definition of AI literacy for primary education also raises questions about what to teach and how to teach it. Additionally, little attention has been devoted to understanding gender differences in learning outcomes within AI literacy primary education.

This study advocates the use of an arts-based transdisciplinary approach for teaching AI literacy to 25 primary school students. A pilot study utilizing mixed methods was conducted to assess the effectiveness of this arts-based approach. Quantitative analysis through a paired *t*-test revealed a statistically significant improvement in AI literacy among students participating in knowledge tests. Moreover, the results of the Mann–Whitney and Kruskal–Wallis tests indicated that gender and age did not impact pre- and post-knowledge test scores. Qualitative analyses further revealed the pedagogical benefits of the arts-based approach, demonstrating that students enhance their conceptual understanding of AI literacy by reflecting on their artifacts. This study contributes to the literature by providing evidence with a small sample size that the arts-based approach can overcome age and gender barriers to accessing AI literacy education and can serve as a means to teach AI thinking.

## 1. Introduction

Artificial intelligence (AI), which is defined as the science and engineering of creating intelligent machines (McCarthy et al., 2006), is an interdisciplinary field of science (Southworth et al., 2023). According to a UNESCO report, AI literacy is crucial to education in the 21st century (Miao & Shiohira, 2022). It not only contributes to global economic competitiveness (Peterson et al., 2021) but also prepares students for the workforce (Zhang et al., 2023). More importantly, encouraging AI thinking (Yim, 2023, pp. 65–90), i.e., fostering creativity and innovation by engaging both humans and nonhumans in collaborative perspectives, is crucial for fostering an ethical understanding of AI data (Benjamin, 2020; Mertala et al., 2022). Addressing challenges such as disinformation (Ali et al., 2021) and promoting students' holistic understanding of AI (Xia et al., 2023; Yim, 2023, pp. 65–90) are core objectives within AI

literacy education. The concept of AI literacy has progressively expanded to encompass various principles, skills, types of knowledge, and multiple academic domains (Long & Magerko, 2020). Furthermore, the topic of AI literacy has substantially broadened to incorporate questions related to the wider societal and ethical impact of AI technology (Ali et al., 2019; Ng et al., 2022).

While research has tended to focus on AI literacy education within secondary and university educational settings (Mertala et al., 2022; Ng et al., 2022), there has recently been a growing interest in teaching AI in primary schools (Dai et al., 2020; Yim, 2023, pp. 65–90), which is facilitated by the emergence of more age-appropriate AI learning tools (Toivonen et al., 2020; Williams et al., 2024). AI literacy is often taught in computer science courses and other scientific settings (Kandlhofer et al., 2016; Touretzky et al., 2023); however, this approach may inadvertently exclude certain individuals from engaging in AI literacy

<sup>\*</sup> University of Cambridge, Faculty of Education, 184 Hills Road, Cambridge CB2 8PQ, United Kingdom.

E-mail address: [hyy25@cam.ac.uk](mailto:hyy25@cam.ac.uk).

learning (Lin, Yu, et al., 2021; Mertala et al., 2022). Despite efforts to investigate the relationship between learning outcomes in AI literacy education and university students' age and gender differences (Jang et al., 2022; Kong et al., 2021; Xia et al., 2023), little is known about such processes in primary schools (Dai et al., 2024; Druga et al., 2019; Mertala et al., 2022). Additionally, there is limited research investigating AI literacy learning activities and pedagogical strategies for the acquisition of AI knowledge by young students without prior computer science and programming experience (Dai, 2024; Yang, 2022), despite the fact that humans increasingly live and work alongside AI machines and technologies.

This paper advocates an arts-based transdisciplinary pedagogical approach in AI literacy education for the development of students' conceptual understanding of AI literacy and their acquisition of AI knowledge. It is paramount that all students have equal opportunities to develop their knowledge of AI literacy (Vartiainen et al., 2020). Prior knowledge of computers and programming should not be considered necessary for developing AI literacy. This study argues that employing an arts-based approach could enhance young students' AI literacy knowledge and more effectively promote gender equality in AI literacy education for all.

## 2. Literature review

### 2.1. AI literacy and AI literacy education

Literacy represents "the basic knowledge and skills needed by all in a rapidly changing world and fundamental human right" (UNESCO, 1997, p. 4). However, with the advancement of AI technologies and computer science (Zawacki-Richter et al., 2019), researchers have attempted to expand the concept of literacy beyond its original focus on reading and writing (Kandlhofer et al., 2016) to include AI literacy (Ng et al., 2022).

The first formal study of teaching AI literacy to young children (Chiu et al., 2021) used LOGO programming and a Turtle robot (Papert & Solomon, 1971). While AI literacy education has begun to expand into primary education (Chiu et al., 2021), AI continues to be considered predominantly a computer science discipline (Kandlhofer et al., 2016; Lao, 2020; Van Brummelen et al., 2021; Wong et al., 2020). This continuing trend has been regarded as problematic by certain scholars who have argued that AI literacy is interdisciplinary and transdisciplinary in nature (Dai et al., 2023; Southworth et al., 2023) and that, therefore, AI literacy education should not be limited to students in computer science classrooms (Druga et al., 2019; Henry et al., 2021; Southworth et al., 2023). With AI technology entering our daily lives and expanding into areas such as health care, transport, and agriculture (Barrat, 2023), AI literacy has been considered an interdisciplinary subject (Southworth et al., 2023) that covers broad topics such as disinformation, deep fakes (CNN, 2023), the importance of data inclusivity (Benjamin, 2020; Mertala et al., 2022), and the societal and ethical ramifications of AI (Ali et al., 2019; Cheng & Yim, 2024). There have also been calls for more student-centered and new pedagogical approaches in AI literacy teaching and learning (Luckin & Holmes, 2016; Rizvi et al., 2023) to encapsulate the entirety of students' educational experiences and foster their holistic understanding of AI (Southworth et al., 2023; Xia et al., 2023).

Moreover, Mertala et al. (2022) highlight a prevalent lack of informed or accurate preinstructional conceptions of AI among primary school students. With this realization, there has been growing advocacy for the integration of AI literacy within formal education (Tedre et al., 2021), with an objective to enhance the conceptual understanding of AI among young students (Chiu et al., 2021). Grounded in the zone of proximal development and scaffolding, Dai et al. (2023) and (2024) argue that students' level of cognitive development at the primary school stage positions them at an optimal juncture for effectively cultivating a conceptual understanding of AI literacy. This perspective emphasizes the importance of focusing on conceptual understanding rather

than requiring technical proficiency in coding or programming for young students (Chiu et al., 2021; Dai, 2024; Mertala et al., 2022).

### 2.2. Inequality in AI literacy education in the primary school context

AI literacy education was previously taught primarily at the university and secondary school levels but has recently started to be expanded to primary school settings (Dai et al., 2023, 2024; Mertala et al., 2022). When available at the primary school level, AI literacy is often taught within computer science and other science curricula (Dai et al., 2020; Touretzky et al., 2023). Recently, more than 10 countries have implemented AI curricula (Miao & Shiohira, 2022). Some countries regard AI literacy as a mandatory part of primary school curricula. For example, the State Council of China introduced its "New Generation Artificial Intelligence Development Plan" (Petersen et al., 2021) with the development of a series of AI textbooks that can be used by primary school students in computer science classrooms (Chiu & Chai, 2020; Dai et al., 2020). In other countries, AI literacy learning and education do not exist as separate subjects in primary school curricula (Touretzky et al., 2023) but have been integrated into computer science and other science curricula (Heinze et al., 2010; Tkáčová et al., 2020; Touretzky et al., 2023), such as those for STEM disciplines (i.e., Science, Technology, Engineering, and Mathematics) (Wang & Cheng, 2021; Yang, 2022). One such example is the AI4K12 Initiative, which was developed in the United States and contains national guidelines (known as "Five Big Ideas") that align with the Computer Science Teachers Association (CSTA) standards and the Next Generation Science Standards (NGSS) (Touretzky et al., 2023).

Arguably, the view of AI literacy education as inextricably linked to computer science and other science subjects may minimize the engagement of female students, due to the societal assumption that science, computer science, and mathematics are more suitable for male students (Jung & Lee, 2021; Leonard et al., 2021). For example, Leonard et al. (2021) conducted a survey in UK schools with 356 Grade 5 (ages 9–10) and 960 Grade 7 (ages 11–12) female students to understand their attitudes toward computing. Their findings suggested that female students express less positive attitudes toward computing than male students do, which may affect their later engagement with computing and computer science learning. Previous studies have also shown that gender may influence primary school students' motivation (Lin, Chai, et al., 2021), anxiety (Dai et al., 2020), and behavioral intentions in AI literacy education (Chai, Lin, Jong, Dai, Chiu, & Huang, 2020; Chai, Lin, Jong, Dai, & Chiu, 2020). Lin, Chai, et al. (2021) revealed that there is a significant gender difference in motivation, with girls perceived to be less motivated to learn AI literacy than boys. Sanusi et al. (2022) explored students' competencies in AI literacy education across genders and school types in Nigerian secondary school contexts, while Xia et al. (2023) used self-determination theory to understand the needs of Grade 9 AI literacy students of different genders and achievement levels. However, more research is required on gender differences in AI literacy learning, specifically in primary school contexts (Dai et al., 2024).

### 2.3. The arts-based approach in transdisciplinary education

There has recently been growing interest in investigating the efficacy of integrating the arts into transdisciplinary education, which involves combining multiple disciplines to enhance learning outcomes (Burnard et al., 2022). One effective method of this integration is arts-based pedagogy (Rhoades, 2021), an educational approach that incorporates the arts into the learning process (Bayley, 2018, pp. 19–50). In this approach, students engage in activities such as creating artworks that support learning objectives in the classroom (Moreno et al., 2023).

Previous empirical studies have shown that the use of arts promotes inclusion by empowering girls to access STEM education and actively participate in their learning (Ma et al., 2022; Martínez et al., 2021). A study conducted by Ma et al. (2022) exemplifies this by categorizing 96

primary students into three groups - girl, boy, and mixed groups - to explore their learning behaviors within the context of STEAM education (i.e., Science, Technology, Engineering, Arts, Mathematics). The findings of the study revealed that, in various aspects, such as high-order thinking analysis behaviors and application behaviors, no significant differences existed between the girl and boy groups. These behaviors encompass the identification of problems, logical reasoning, and the application of subject knowledge and technical skills to solve problems. Similarly, [Martínez et al. \(2021\)](#) adopted an arts-based approach, infusing a creative maker mindset into ten primary schools in Spain through a design-based thinking program. They aimed to assess whether such an approach could narrow the gender gap in STEAM disciplines. Despite boys demonstrating a greater level of prior experience, greater ownership of digital devices outside of school, and more frequent participation in extracurricular activities involving technological devices, the pre- and post-assessment conducted in their study indicated increased interest, motivation, self-efficacy, and engagement across all genders. Collectively, these studies provide valuable evidence for reducing existing gender stereotypes in transdisciplinary education. However, while there is evidence that the arts can help promote inclusivity - which involves the existence of greater educational opportunities and an environment where everyone, regardless of gender, can participate, engage, and receive the support needed to achieve equal outcomes - its application in AI literacy education remains under-explored.

Despite previous studies revealing that the arts-based approach has demonstrated some effectiveness in engaging ([Lage-Gómez & Ros, 2023](#)) and increasing the motivation ([Tee, 2022](#)) and self-efficacy ([Vicente et al., 2021](#)) of young students in transdisciplinary areas such as STEM education, there has been little focus on the use of such an approach in AI literacy teaching. Teaching AI knowledge to primary students in an age-appropriate and engaging way is challenging ([Yang, 2022](#)). Equally challenging is defining AI literacy for young students ([Ali et al., 2021](#); [Ng et al., 2022](#)). Previous research has promoted constructivist approaches to teaching AI literacy ([Ali et al., 2019](#)), such as project-based ([Narahara & Kobayashi, 2018](#); [Shamir & Levin, 2021](#)) and game-based ([Henry et al., 2021](#); [Voulgari et al., 2021](#)) approaches. [Henry et al. \(2021\)](#) further find that these dominant approaches in AI literacy education place too much emphasis on the technical aspects of AI literacy while overlooking the necessity for AI literacy to explore ethical and social questions. There is also an underrecognition of the potential of arts-based pedagogy ([Bayley, 2018](#), pp. 19–50; [Su, Yim, et al., 2024](#)), which could contribute to providing students with a comprehensive understanding of AI literacy ([Yim, 2023](#), pp. 65–90). The influence of the arts on creative and cognitive development is often overlooked ([Burnard et al., 2022](#)), despite evidence that incorporating creativity into school curricula can nurture students' innovation ([Weng et al., 2023](#)). [Rodrigues-Silva and Alsina \(2023\)](#) report significant cognitive gains among children once the arts are incorporated into learning activities and curricula and show that the inclusion of the arts promotes the development of students' knowledge and agency. [Santi et al. \(2021\)](#) advocate the integration of the arts in science to develop young children's thinking skills and creativity, as well as their scientific and technological knowledge and abilities.

### 3. Research gaps and questions

Three key research gaps in the topic have been identified. Considering the important role of technology in everyday life in the 21st century, AI literacy education should be promoted in primary schools instead of being limited to secondary school or university settings. However, the conceptions of primary school students and their understanding of AI literacy are underexplored. This deficiency highlights the need for more research on AI literacy education for younger students. Second, although previous research has proposed different methods for AI literacy education, arts-based approaches remain unexplored. Third, previous studies have not sufficiently examined the learning outcomes

of age and gender within AI literacy education. Closing these gaps could contribute significantly to the development of inclusive and equitable AI literacy education in primary school contexts.

This study investigates whether an arts-based approach could enhance young students' AI knowledge and their conceptual understanding of AI literacy and promote gender equality in AI literacy education for primary school students. Thus, the following three research questions are formulated.

RQ1: What are the effects of an AI curriculum with arts-based pedagogy in helping primary students acquire AI knowledge and increase their conceptual understanding of AI literacy?

RQ2: In what ways does arts-based pedagogy enhance the inclusiveness of AI literacy education by enabling students of all genders and ages to participate and benefit?

RQ3: How does the art-based approach enhance young student's engagement with AI literacy?

## 4. AI literacy primary education curriculum

### 4.1. Theoretical framing

The theoretical framework of this study is grounded in a sociocultural perspective, which posits that knowledge is constructed through interactions with others ([Vygotsky & Cole, 1978](#)). This aligns with Vygotsky's socio-cultural activity theory, which emphasizes the critical role of tools and technologies in mediating actions and promoting positive changes in learning ([Dangol et al., 2024](#); [Watson & Romić, 2023](#)). The AI literacy program is designed to promote a shift from traditional human-centric teaching methods to a post-humanistic approach. This approach views reality as interconnected, involving both human and non-human entities, such as AI technology, that coexist and mutually influence each other ([Gibson et al., 2023](#); [Su, Yang, et al., 2024](#); [Wegerif & Major, 2023](#)). In the context of AI literacy education, these perspectives highlight the importance of recognizing and valuing diverse contributions from both human and non-human actors. Such an inclusive approach may enrich learning experiences by fostering a deeper understanding of AI's societal implications and potential through a broader, more integrated lens.

### 4.2. Learning content of AI literacy curriculum

This study employs the 'Six Big Ideas of AI literacy' intelligence-based primary school curriculum ([Yim, 2023](#), pp. 65–90), which was derived and adapted from the Five Big Ideas proposed by [Touretzky et al. \(2019\)](#), with AI thinking included as the sixth Big Idea. In the present study, the term AI thinking refers to the construction of multiple different perspectives that are aimed at generating creative and innovative ideas and encouraging effective engagement and collaboration among both humans and nonhumans (i.e., peers, arts materials and AI machines) in their AI literacy learning. The AI thinking perspective advocates fostering creative and dialogic interactions, and it serves not only to advance AI development but also to address AI ethics and data justice and to contribute to building a sustainable and inclusive world. The Six Big Ideas are listed in [Fig. 1](#) as follows:

Big Idea One: Perception - By using sensors, computers can perceive the world.

Big Idea Two: Representation and reasoning - AI agents provide representations of the world for reasoning purposes.

Big Idea Three: Learning - Computers can learn from data.

Big Idea Four: Natural interaction - AI agents require various types of knowledge to interact with humans naturally.

Big Idea Five: Societal, ethical, and environmental impacts.

Big Idea Six: AI thinking for understanding data critically and creating new ideas.

In addition, the lesson plans and objectives of the AI course are

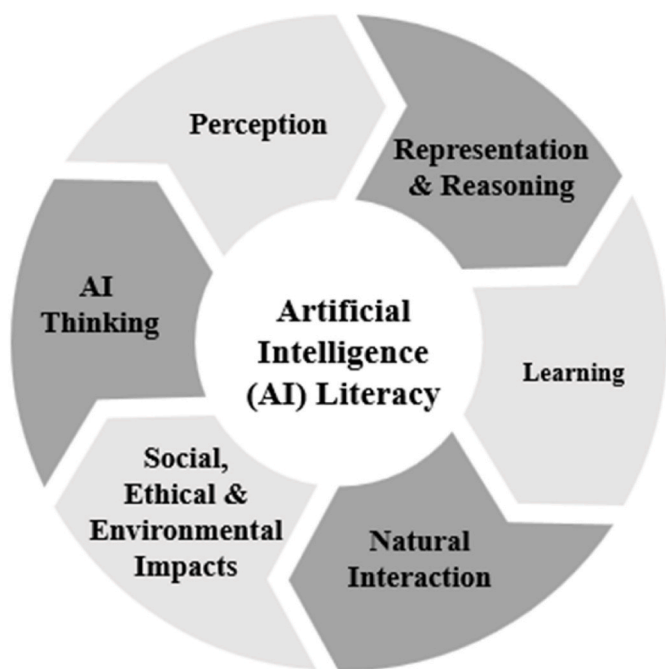


Fig. 1. The six big ideas of the AI literacy intelligence-based curriculum for primary school students (Yim, 2023).

shown in Table 1.

### 5. Methodology

An exploratory pilot study with mixed methods was conducted to evaluate the impact of the arts-based pedagogical approach.

#### 5.1. Participants

Twenty-nine primary four students (equivalent to Key Stages 2–4 in UK schools or Grade 3 in US schools) from a Hong Kong primary school

Table 1  
Lesson plans and objectives of the AI course.

Lesson	Learning objectives	Example Activities
(1) Perception, Representation and Reasoning (Big Idea 1 & 2)	Understand what AI is, why it is relevant now, and the differences between rule-based and data-based approaches	Turing test (student vs. ChatGPT, SIRI), AI arts generation, and computer vision demonstrations, “Imagining you as an AI” art-making activity; Make a decision tree activity
(2) Machine learning, Human-AI interaction (Big Ideas 3 & 4)	Gain an understanding of machine learning, the concept of data, and the role data plays in interacting with AI systems	<a href="https://quickdraw.withgoogle.com">https://quickdraw.withgoogle.com</a> ; Physical AI learning tools (e.g. AI drawing robot, dance bot, AI voice and sound robot); Interact with ChatGPT
(3) Computational & AI Thinking (Big Idea 6)	Gain an understanding of coding, computational thinking concepts, and AI thinking	Dance with codes, Thinking with ChatGPT, AI toy car assembly, design racing tracks, and participate in group car racing competitions
(4) AI Ethics (Idea 5)	Understand how AI is used in our daily lives, comprehend the societal, ethical, and environmental implications of AI, and recognize the critical role of data	Drama activity; Better Off Ted <a href="https://www.youtube.com/watch?v=AmUC4m6w1wo">https://www.youtube.com/watch?v=AmUC4m6w1wo</a>

were enrolled in this AI literacy course. Two students withdrew before the beginning of the course due to time conflicts with other school activities. Two other students did not complete the whole course due to sickness and absences due to sports and music competitions. Their data were removed. In total, data from 25 students, comprising 7 girls and 18 boys, were used. The students, aged 9 (n = 11), 10 (n = 12), and 11 (n = 2), were randomly assigned to different groups. To the best of the author’s knowledge, the students who participated in this study were no different in terms of their socio-demographic characteristics from students at any typical school in Hong Kong. The AI literacy course was delivered in four 90-min sessions between March and April 2023 as part of the after-school curriculum.

#### 5.2. Procedure

Students’ first encounter with AI in this course was the “Imagining you as an AI” art-making activity, which was based on Braidotti’s (2013) concept of the relationship between the human and the posthuman. Through this exercise, students can work with AI to explore creative aspects of their identities, pushing the boundaries of innovation and artistic expression (Boddington, 2023). In this activity, an art form was integrated with AI and AI literacy to create a new pedagogical and dialogic learning space for the students (Bayley, 2018; Wegerif & Major, 2023; Yim, 2023, pp. 65–90), in which they learned about AI and AI literacy through arts-based activities. The activity required students to imagine themselves as if they were AI. Students were provided with arts materials and AI learning tools from which they could choose freely to encourage them to consider what AI means to them. For example, the AI drawing robot, shown in Fig. 2, was equipped with a sensor enabling autonomous tracing of students’ drawings. This interactive tool allowed students to experiment with various lines, colors, and shapes while observing the robot’s responses. Through this drawing, students gained insight into the reasoning and mechanisms underlying AI technology, as well as the essential data significantly impacting the performance of the robot. By integrating this interactive tool and activity into the study, the aim was to expand students’ learning space, fostering the development of their AI thinking and enabling them to make informed judgments about data usage. Students then engaged in discussions and drama group activities and designed artifacts to demonstrate their conceptual understanding of what AI is and what AI literacy means to them. In addition, students were taught the learning content of the Six Big Ideas of the AI literacy primary curriculum.

Finally, stimulated recall interviews were used (Calderhead, 1981), which involved inviting students and their parents to Zoom meetings in which the researcher played the students’ lesson recordings and displayed their artifacts so that the students could show and tell what they had learned to their parents. This knowledge visualization approach was intended to enable young students to create visual representations (i.e., artifacts) (Wang et al., 2011), aiding them in demonstrating their conceptual understanding of AI literacy to their audience in an understandable format.

#### 5.3. Ethics

The procedures in this study were approved by the University of Cambridge. It was reported that the study did not involve any ethical problems or risk issues. Before the start of the study, written consent forms were received from the participating school principals, teachers, and parents/guardians. Oral assent and written consent were then obtained from the students. The use of images, voices, videos, and artifacts for this study was authorized, and the names of the participants were anonymized.

#### 5.4. Data collection and analysis

This was an exploratory study involving primary school students and

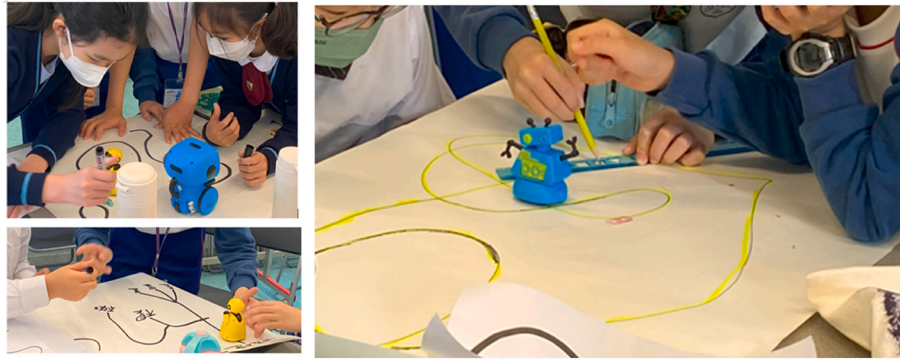


Fig. 2. AI drawing robot.

their parents. Both qualitative and quantitative data were used to inform the study (Creswell, 1999). The following data were collected for the study: 1) demographic information regarding the student participants, which was collected prior to the AI literacy course; 2) pre- and post-knowledge tests in a survey format, which were completed by the student participants on the first and last day of the AI literacy course, respectively; 3) students' artifacts and stimulated recall interviews (including questions such as "Can you explain what you created?"; "Can you describe what you were doing and thinking at this moment?"; "What did you learn?"), where students' artifacts and reflections were also posted on Google Padlet and shared with classmates and teachers, allowing them to resonate with their experiences as shown in Appendix II; and 4) using responses from parents to post-intervention open questions in a survey to triangulate the results (e.g., "Have you seen any improvements in your children's AI knowledge after taking this AI learning program?"; "Based on your observation, how have your children benefited through this project by using arts-based methods?").

#### 5.4.1. Quantitative analysis

Surveys were used to collect students' demographic information. The pre- and post-knowledge tests were distributed via Qualtrics (an online survey software). These tests included 19 multiple-choice questions about AI knowledge, with one point given for correct answers and none for incorrect answers. Since an effective assessment of students should provide direct evidence of educational progress (Suskie, 2018), the knowledge test was designed based on the learning content of the six Big Ideas to directly measure students' learning outcomes. Initial drafts of the learning materials and knowledge tests were discussed and refined before the AI course began, by three information technology teachers at the participating school in Hong Kong, who had one, five, and 25 years of teaching experience respectively. Additionally, these teachers engaged in collaborative discussions among themselves, focusing on the selection of AI learning tools and the refinement of the tests, providing feedback on usability and clarity, such as suggesting replacing technical terms with simpler language and clarifying concepts to reduce ambiguity. The researcher implemented revisions accordingly, and, before the AI course began, the teachers conducted a final review to confirm that the revisions addressed their feedback. Sample questions are listed in Appendix I. Considering that students may not have understood the words in the questionnaires, they were read aloud by the researcher. Students were also asked to rate their satisfaction at the end of the full course.

The Statistical Package for the Social Sciences (SPSS) was used to compute the paired sample *t*-test to compare the differences between students' pre- and post-knowledge acquisition of AI learning. The Mann-Whitney test was used to compare the differences between the gender groups, while the Kruskal-Wallis test was used to investigate whether students' age had a measurable effect on their AI knowledge acquisition.

#### 5.4.2. Qualitative data analysis

Students' artifacts were included in the qualitative data analysis. The semiotics and iconography approaches were used to study the signs and symbols in the artifacts created by the students (Van Leeuwen, 2001, pp. 92–118). The researcher, who engaged in immersive interactions with students, participated in their AI learning activities, was involved in their classroom conversations, and attempted to gain an in-depth understanding of their viewpoints in the stimulated recorded interviews, was both an insider and an outsider. From an ethnographic perspective, thematic analysis was adopted to code the data and identify any meaningful themes and patterns emerging from the dataset (Braun & Clarke, 2006). The coding scheme is shown in Table 2. To ensure objectivity in the coding process, the dataset was coded separately by two coders, that is, the author and an independent researcher. The two coders then discussed, reviewed, and resolved any disagreements and discrepancies to ensure consistency and validity of conclusions.

## 6. Findings

RQ1: What are the effects of an AI curriculum with arts-based pedagogy in helping primary students acquire AI knowledge and increase their conceptual understanding of AI literacy?

This section reports the quantitative and qualitative findings regarding the effectiveness of an AI arts-based curriculum in enhancing students' AI literacy in terms of their AI knowledge and their conceptual understanding of "what is AI literacy?".

**Table 2**  
The coding scheme.

Theme	Example	References
AI Ethics, and impacts	Societal, ethical, and environmental impacts (Big Idea Five)	Ethical framework for AI and digital technologies (Ashok et al., 2022)
AI thinking	Understand AI thinking (Big Idea Six)	AI thinking in the Six Big Ideas model (Yim, 2023, pp. 65–90)
Computational thinking	Natural Interaction (Big Idea Four)	Computational thinking encompasses the process of formulating problems in a manner in which solutions can be expressed through computational steps and algorithms (Wing, 2006)
Critical data literacy	Understand how computers learn from data (Big Idea Three)	Allow students to use data in a critical way (Tygel & Kirsch, 2016)
Understanding AI and using AI in Digital literacy	Understand perception (Big Idea One); representation and reasoning (Big Idea Two)	AI Literacy Competencies Framework (Long and Magerko; 2020)

### 6.1. Quantitative analysis of the students' progress between the pre- and post-knowledge tests

To answer RQ1, two variables were computed from the sums of scores on 19 knowledge test questions aimed at measuring AI knowledge before and after the test. The new variable, representing the differences between the post-test and pre-test scores, was found to be normally distributed, indicating that the data meet the assumptions required for parametric testing (Table 3), as confirmed by the Shapiro-Wilk test ( $W = 0.981$ ,  $p = 0.904 > 0.05$ ). Consequently, a paired sample  $t$ -test was conducted, with results in Table 4. There is a statistically significant difference between the knowledge acquisition score of students before (mean = 10.64; standard deviation = 3.29) and after the AI course (mean = 16.2; standard deviation = 3.014). The average pre-course knowledge was 10.64 out of 19, whereas the average post-course knowledge was 16.2 out of 19, showing an increase of 5.56. The one-sided  $p$ -value was  $<0.001$  and the two-sided  $p$ -value ( $P = 0.001 < 0.05$ ) indicated that the null hypothesis of the equality of means could be rejected and that there were significant differences between the pre- and post-test values.

In addition, this study has an effect size of 4.214, which is considered large according to Cohen's criteria, which classifies an effect size greater than 0.8 as large. This means the research findings have a practical significance. The overall Cronbach alpha is 0.744, ranging from 0.683 (pre-test) and 0.793 (post-test). This result indicates satisfactory internal consistency.

### 6.2. Qualitative analysis of students' conceptual understanding of AI literacy

Students' conceptual understanding of AI literacy was reported through their artifacts and data from stimulated recall interviews. Four themes were identified (Table 5).

Different variations of the artifacts were produced, with their key characteristic being that they simultaneously represented a human feature (e.g., brain, hair) ( $n = 17$ ), nonhumans ( $n = 9$ ) (e.g., butterfly, a cartoon robotic cat, and masquerade masks), computer-like features ( $n = 5$ ) (e.g., circuit symbols, a computer mouse), and nature (e.g., camouflage) ( $n = 1$ ). These images of AI masks were not real AI images; however, they formed a narrative from the students' perspective and demonstrated their conceptual understanding of AI literacy in terms of digital literacy, AI ethics, computational thinking, societal and ethical impact, critical data literacy, and AI thinking.

**Understanding and using AI in digital literacy:** Most of the artifacts demonstrate the students' understanding of perception (Big Idea One) and representation and reasoning (Big Idea Two), indicating that AI machines perceive the world using sensors and applying rule-based logic ( $n = 17$ ). On the one hand, the visual images and symbols used in the students' artifacts represent human physical features in an exaggerated manner, most notably the eyes, the brain, the eyelashes, and the hair (Fig. 3).

On the other hand, a human personality is also reflected in the students' AI artifacts, which demonstrates their understanding of AI literacy as a way of "becoming", i.e., as involving a process of transformation and creation, whereby students become AI characters through their interactions with peers, arts materials, and AI technologies.

In their performances as their AI characters and their engagement in doing, knowing, and being with their bodily movements and gestures, the students demonstrated an understanding of the nature of AI and AI literacy. For example, three of the masks were painted with beards and

crowns in the style of the masks often used in Chinese opera (Fig. 4). The students' hand gestures also resembled those of actors in Chinese opera, who communicate their role and personality without speech. Their exaggerated body movements and stylized hand gestures contributed to expressing the personality of their AI characters. The mask worn by the student on the left-hand side of Fig. 4 represents a young AI character with a long face outlined by a thin black line, with black fish-shaped cheeks and eyes, wearing a blue royal crown. In the Chinese operatic tradition, the color black is associated with justice and decisiveness, characteristics that the student appears to ascribe to AI algorithms and AI reasoning. In contrast, the playful physical gesture of the student in the center of Fig. 3, alongside the smiling face on his mask with colors matching those of his clothing, appears to depict a friendly AI character welcoming the human. Meanwhile, the orange and yellow tones of the mask worn by the student on the right-hand side of Fig. 6 represent tranquility and innocence in Chinese culture. The youthful hand gestures of the student contribute to this idea of innocence, alongside a willingness to learn and interact with humans and nonhumans.

**Computational thinking:** As shown in Fig. 5, two students designed their masks with the use of computing tools (binary codes, circuit symbols, and computer components such as cables and computer mice) in the design, which demonstrated their understanding of computational thinking (i.e., the thought process involved in formulating a problem solution, represented in terms of steps and AI algorithms) and the idea that computers learn from data (Big Idea Three). Students imagined themselves as AI and engaged in coding and programming by identifying patterns from the data and designing algorithms. Their thought processes indicated their acknowledgment of their personal limitations in formulating and solving problems through a step-by-step process. The students also interpreted the possibility of incorrect and poor-quality data endangering human lives as the product of the cold and mechanical nature of computers and machines. To emphasize the importance of data quality, students added vibrant colors (red, orange, yellow, blue, and green) to reflect the urgent need to include humans in computational thinking.

**AI ethics concerning scientific literacy and societal impacts:** Some of the artifacts demonstrated students' appreciation of the importance of scientific literacy, which is the knowledge and understanding of scientific concepts and processes required to inform decision-making in the interests of society, the community and nature. For example, the three artifacts in Fig. 6, depicting a blue puppy, a phoenix, and a butterfly, indicate the students' view of the AI world as encompassing nonhuman entities. The puppy is a pet that often accompanies humans, while the phoenix is a mythical firebird similar to the Chinese "fenghuang". The phoenix represents rebirth and the restoration of life and nature. However, butterflies are affected by habitat loss and climate change. Treating nonhumans as stakeholders is essential for informing decision-making, as it helps humans consider their ecological impact and promotes ethically responsible AI development.

Similarly, the two artifacts in Fig. 7 demonstrate the students' understanding of patterns and relationships in their environment, particularly their ability to use geometric shapes and triangles to represent the concept of balance. The triangular shape can be interpreted as representing the coexistence of AI, humans, and nature, symbolizing a harmonious balance and stability. This balance is perhaps also reflected in the student's choice of mask color (the right-hand side of Fig. 6), which matches that of his clothing, which arguably further indicates the student's desire for harmony between AI and humans.

**Ethical and societal impact:** Several students' artifacts indicate the ways in which they understand the interaction between AI and humans (Big Idea Four) and society (Big Idea Five). In the artifact on the left-hand side of Fig. 8 (Yim, 2023), the human sensory organs (the eyes, nose, and mouth) are painted black. Students comprehend that AI perceives the world using sensors, and by painting its sensory organs in black, they appear to attribute human characteristics to AI. They design AI with camouflage patterns, similar to those found in nature, to conceal

**Table 3**  
Test of normality (Shapiro-Wilk).

	Shapiro-Wilk	p
PostSum-PreSum	0.981	0.904

**Table 4**  
Paired sample *t*-test for the comparison of the pre and post AI course knowledge scores.

Paired samples statistics									
	Mean		N		Std Deviation		Std Error Mean		
Pre-test	10.64		25		3.29				0.658
Post-test	16.2		25		3.014				0.603
Paired samples test									
	Mean	Std Deviation	Std Error Mean	95% Confidence Interval		t	df	Significance	
				Lower	Upper			One-Sided p	Two-Sided p
Pre and Post Test	-5.56	4.214	0.843	-7.299	-3.821	-6.597	24	<0.001	<0.001
Paired Samples Effect Sizes									
	Cohen's d	Hedges' correction	Standardized	Point Estimate	95% Confidence Interval				
					Lower	Upper			
Pre and Post Test			4.214	-1.319	-1.793				
			4.352	-1.278	-1.793				
Reliability statistics									
	Cronbach's alpha			Cronbach's alpha based on standardized items					
Pre-test items	0.683			0.656					
Post-test items	0.793			0.803					
Combined Pre and post-test items	0.744			0.758					

**Table 5**  
Four themes of the student artifacts.

Artifact	N	Example
Human-like features	17	brain, hair
Nonhumans	9	butterfly, cartoon robotic cat
Computer-like features	5	circuit symbols, a computer mouse
Nature	1	camouflage

its presence, positions, and intentions. This draws inspiration from the natural world, where animals use camouflage to blend into their surroundings for self-protection and hunting purposes. In other words, the students appear to acknowledge that AI is everywhere but perhaps lack sufficient AI literacy to identify all the hidden examples of AI technology in their daily life.

The artifact on the right of Fig. 8 is a young man with a human skin tone, neatly trimmed hair, and well-groomed eyebrows, pictured having woken up in the morning with his pajamas still on. He, as an AI, is getting dressed and preparing himself for pleasant social interactions. Such human etiquette is presented as a means to enable human and nonhuman interactions, and the student's artifact suggests that AI possesses human behavioral characteristics. There appears to be an

expectation by the student for AI to display a degree of ethical behavior and social respect so that it can harmoniously collaborate with humans.

**Critical Data Literacy:** Two students demonstrated an understanding of critical data literacy (Big Idea Six) by naming their masks Kamehameha and Doraemon, both of which are Japanese cartoon characters (Fig. 9). Doraemon, an earless robotic cat, travels back in time with his time machine door (see the image on the right-hand side of Fig. 9). As shown in Fig. 10, the Doraemon in the artifact has two pairs of eyes, with one pair representing Doraemon's willingness to follow his friend's instructions whenever he needs help and the other pair representing the eyes of humans who exploit technological inventions (such as AI) to satisfy their own human desires. This artifact communicates the idea of AI literacy, particularly critical data literacy, which is understood as using AI ethically and critically to avoid exploitation by human individuals.

The student artifact shown in Fig. 11 depicts Kamehameha, a fireball that emerges from the hands of the Japanese cartoon character Goku (who is a young boy with superhuman abilities) in episodes of the TV cartoon *Dragon Ball* (IMDB, 2023). The orange fireball on the white face represents the AI brain and is the symbolic Kamehameha superpower, which was invented by the fictional martial arts master, Mr. Roshi, who had spent 50 years perfecting it. Surprisingly, Goku can perform this task



Fig. 3. Students' artifacts with human physical features.



Fig. 4. Students' artifacts in the style of Chinese opera.



Fig. 5. Students' artifacts with computer-like features.

in 50 s and can decimate an entire planet with a single shot of the Kamehameha superpower. The name of this artifact, Kamehameha, highlights the dangers of AI as well as questions about who is responsible for the damage it can cause. These two artifacts also demonstrate that the more data that are fed into AI, the more powerful AI will become. Students appear to be aware of the importance of understanding the role of the data as well as the potential positive and negative impacts of AI.

**AI Thinking:** Fig. 12 shows five students presenting their group artifacts in class, which they titled "What does a mouse mean to AI?" This presentation was delivered in a drama format and involved one student

performing the role of an AI and the other students performing the role of humans interacting with AI and each other. The students placed themselves in the "shoes" of an AI machine as a way of making sense of its reasoning process. As part of the exercise, the students drew various types of mice: (i) two blue computer mice, (ii) three computer-mouse-shaped mice outlined in blue (i.e., two colored in red and one with two ears and a curly tail), and (iii) a blue cartoon mouse with a red outline (Fig. 13). Drawing a computer mouse to resemble the animal mouse and painting it in red, the student's intention was to deceive the AI by presenting it with data that fell outside the expected colors and



Fig. 6. Students' artifacts, depicting a blue puppy, a phoenix, and a butterfly. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)



Fig. 7. Students' artifacts with mild asymmetry and a degree of cubism.

patterns that it was trained to detect. The students therefore demonstrated the limitations of AI and suggested solutions to improve its quality, such as enlarging its dataset and providing it with clearer and more accurate data (e.g., more colors and different types of mice).

In addition, the use of drama and art materials helped to expand the students' skills in AI thinking (Big Idea Six), which can be defined as the ability of humans to use different perspectives to conceptualize AI by effectively interacting and collaborating with other humans as well as with nonhumans. By effectively collaborating with humans and nonhumans, students used their AI thinking skills to question the existing AI data (i.e., the two blue computer mice) and explore other new possibilities (i.e., introducing different colors and shapes of mice), which would result in the advancement of the AI system. They employed art and drama to explore the problem of incomplete data and improve their conceptual understanding of AI literacy in an enjoyable and memorable way. The students' drawings of the four additional mice also provided new visual evidence of the transformation and expansion of their AI thinking skills.

In summary, the qualitative analysis in this study revealed that students' representation of AI in their artworks mirrors their conceptual understanding of AI literacy. This understanding encompasses 1) comprehending AI and using AI in the realm of digital literacy; 2) computational thinking, highlighting the involvement of AI through

computational steps and algorithms; 3) the ethical dimension of AI, emphasizing informed decision-making for the benefit of society, community, and nature; 4) the role of data in preventing exploitation by individuals with wrongful intentions; 5) AI in relation to societal and ethical implications; and 6) the development of students' AI thinking to explore new possibilities for the advancement of AI systems.

RQ2: In what ways does arts-based pedagogy enhance the inclusiveness of AI literacy education by enabling students of all genders and ages to participate and benefit?

The findings show that AI literacy primary education with arts-based pedagogy contributes to the inclusiveness of AI education by enhancing students' knowledge of AI literacy regardless of their gender and age. The results from the Mann-Whitney and Kruskal-Wallis tests in SPSS are discussed.

### 6.3. Assumption checks

The Shapiro-Wilk test of normality was used to determine whether the gender and age data were normally distributed. The results indicate that the null hypothesis for gender ( $p = 0.04$  and  $0.057$ ) and age ( $p = 0.023$  and  $0.031$ ) indicates that the data are not normally distributed



Fig. 8. Students' artifacts reflecting the concepts of ethical and societal impacts.



Fig. 9. Images of Kamehameha (left) and Doraemon (right), Japanese cartoon characters.

(Table 6).

The results of a nonparametric Lavene test showed nonsignificant results for gender and age, which had  $p$  values of 0.573 and 0.416, respectively (Table 7). The assumption of homogeneity of variance was met. Thus, the results of the assumption checks on normality and equality of variances suggest that nonparametric tests should be used.

#### 6.4. Comparison between the boy and girl groups

A Mann–Whitney  $U$  test was applied to determine whether there were significant differences between the pre- and posttest rank sum scores of girls and boys in terms of their acquisition of AI literacy knowledge. The test was two-tailed or nondirectional. First, Table 8 shows that, in the pretest, there was no statistically significant difference between the girl group and the boy group ( $U = 58$ , 2-tailed  $p = 0.761 > 0.05$ ). There were no significant differences between the girl group and the boy group. Posttest scores were not significantly different between the girl group and the boy group ( $U = 62.5$ , 2-tailed  $p = 0.975 > 0.05$ ). In conclusion, the lack of a significant difference between the boy and girl groups in the pre- and post-knowledge test rank sum scores indicates

that gender-based differences do not explain the effectiveness of arts-based pedagogy in enhancing AI literacy.

Table 9 shows the results of the Kruskal–Wallis  $H$  test, which was conducted to examine whether age had a measurable effect on the pre- and post-knowledge scores. The results indicate a nonsignificant difference in terms of the pre-knowledge test,  $\chi^2(2) = 1.667$ ,  $p = 0.434 > 0.05$ , and the post-knowledge test,  $\chi^2(2) = 0.734$ ,  $p = 0.693 > 0.05$ , with a 95% confidence interval. Therefore, this lack of a significant difference between the different age groups indicates that age-based differences do not explain the effectiveness of arts-based pedagogy in enhancing AI literacy.

RQ3: How does the art-based approach enhance young student's engagement with AI literacy?

The findings reveal that, to a large extent, the arts-based approach enhances young students' engagement with AI literacy learning. This conclusion is based on students' face validity of course satisfaction as well as from the perspective of two groups of stakeholders: 1) the parents of student participants and 2) student participants.



Fig. 10. Student's artifact demonstrating the concept of Doraemon, a Japanese cartoon character.

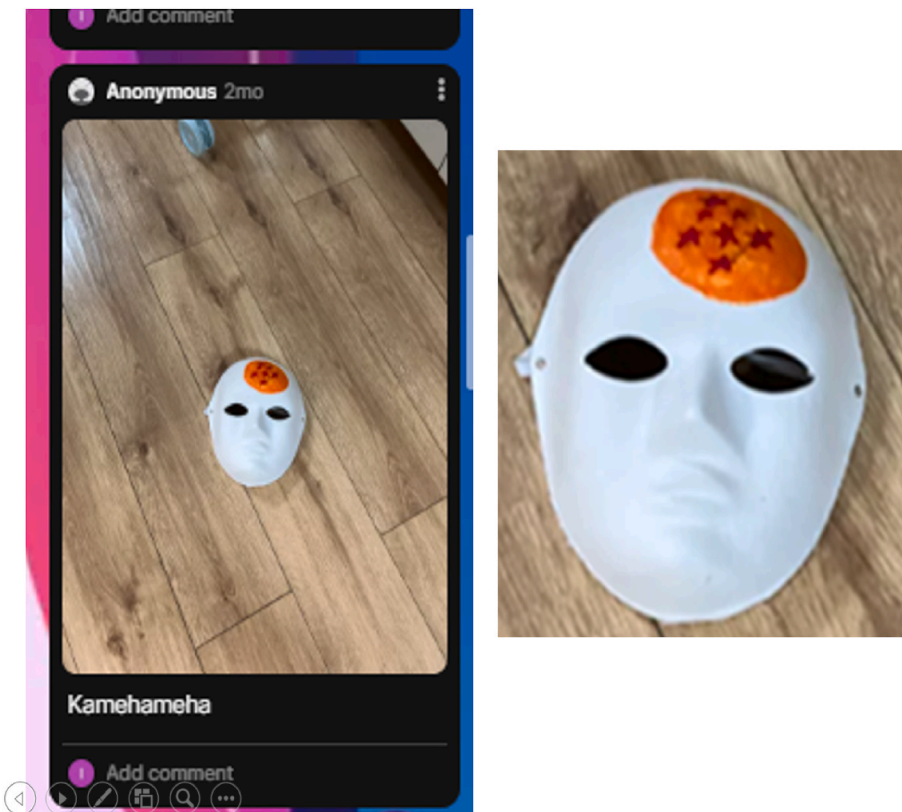


Fig. 11. Student's artifact depicting "Kamehameha", a Japanese cartoon character.

### 6.5. Face validity

All students who completed the course were asked to rate their satisfaction with the AI literacy program on a Likert scale from 1 (strongly dissatisfied) to 4 (strongly satisfied) at the end of the last class. The results support that the design goal was achieved, as over 88% of students expressed that they were satisfied or strongly satisfied with the arts-based pedagogical approach in their AI literacy learning (Table 10).

### 6.6. The parents' and students' perspectives

In general, parents who participated in the post-Zoom meeting (n = 13) did not initially know what their children had learned at school. After their children shared their AI learning and artifacts, most parents perceived that arts-based pedagogy was age-appropriate for their children in building a solid conceptual understanding of AI. Some reported that they found that the course motivated their children and enhanced their interest and engagement in AI literacy learning.

The following is an example of a response from a parent:

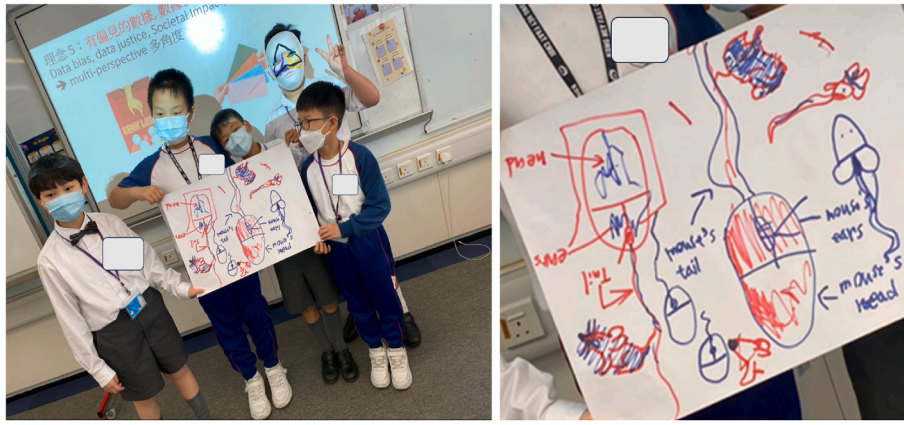


Fig. 12. Group artifact with the concept “What does a mouse mean to AI?”

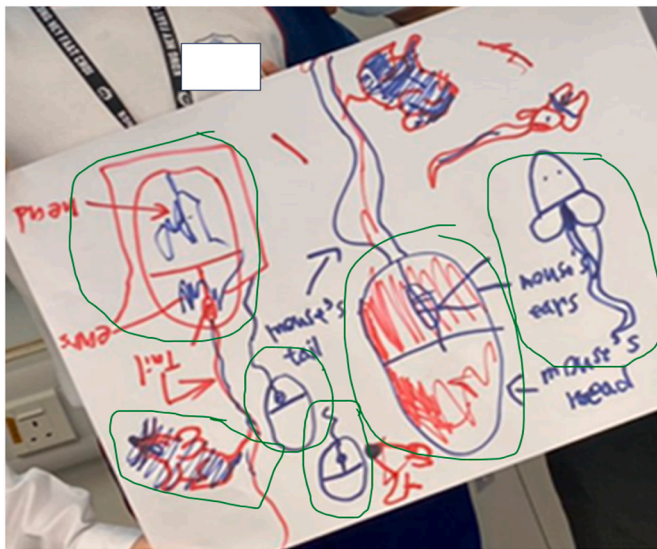


Fig. 13. The six mice circled in green. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 6  
Test of normality (Shapiro–Wilk).

Gender	Shapiro–Wilk	p
PreSum Boys	0.942	0.309
Girls	0.963	0.844
PostSum Boys	0.829	0.004**
Girls	0.815	0.057
Age	Shapiro–Wilk	p
PreSum 9	0.960	0.768
10	0.92	0.287
11	–	–
PostSum 9	0.829	0.023*
10	0.844	0.031*
11	–	–

Table 7  
Test of equality of variances using a nonparametric Levene’s test.

Posttest	F	df	P
Gender Rank_diff	0.327	1	0.573
Age Rank_diff	0.912	1	0.416

Table 8  
Comparison of the Mann–Whitney test results between the boy and girl groups.

Ranks	PreSum			
	Gender	N	Mean Rank	Sum of Ranks
PreSum	Boys	18	13.28	239
	Girls	7	12.29	86
	Total	25		
PostSum	Boys	18	12.97	233.5
	Girls	7	13.07	91.5
	Total	25		
		PreSum	PostSum	
Mann–Whitney U		58	62.5	
Wilcoxon W		86	233.5	
Z		–0.304	–0.031	
Asymp. Sig. (2-tailed)		0.761	0.975	
Exact Sig. [2*(1-tailed Sig.)]		.790 <sup>b</sup>	.976 <sup>b</sup>	

a Grouping Variable: Gender.  
b Not corrected for ties.

Table 9  
Kruskal–Wallis test.

Ranks	Age	N	Mean Rank	
PreSum	9	11	12.91	
	10	12	12.04	
	11	2	19.25	
	Total	25		
PostSum	9	11	13.77	
	10	12	12.96	
	11	2	9	
	Total	25		
		PreSum	PostSum	
Kruskal–Wallis H		1.667	0.734	
df		2	2	
Asymp. Sig.		0.434	0.693	

Table 10  
Course rating.

Course rating	N =	%
Strongly Dissatisfied	2	8%
Dissatisfied	1	4%
Satisfied	16	64%
Very Satisfied	6	24%
Total	25	100%

P3: “I noticed that he has been searching the whole house for arts materials, paper cups, plastic bottle caps, and even used the drill to make his first AI rocket without my help. In the past, he did not bother to do this kind of assignment. I notice that this course inspires my son to be more creative, develops his critical thinking in designing, and he becomes more confident in learning”.

This parent perceived that arts-based pedagogy was able to help her children become more self-motivated in AI learning and develop creativity and critical thinking skills. This student artifact is shown in Fig. 14.

Another student presented his learning to his father as follows:

S2 “I like the drama and dance in this course the most, as unlike other lessons, I do not need to sit still. I can move my body in ways such as jumping, running, moving forward, and making other body gestures to learn the AI algorithms to complete a task. And I used to think that cameras were AI, but I now understand what AI is. Since AI uses sensors to perceive the world, a camera alone cannot be AI”.

The findings demonstrate that creative learning and teaching enhance students’ interests and motivate them to learn AI. More importantly, it helped this student to correct his misconceptions about AI.

His father elaborated:

P2 “I think the use of arts is a good idea, as it can cater to different ages and levels of students in the same classroom to learn the conceptual concepts of AI. I noticed that my son is learning more vocabulary about AI and a thorough conceptual understanding about AI. However, he needs to invest more time in the future in order to develop his AI skills such as how to code and do programming with AI.”

S2 agreed and stated:

“Yes, I want to keep learning AI in the future, because I find it very fascinating.”

Responses from these parents and students suggest that arts-based pedagogy helps to enhance their children’s interest in future AI literacy learning and correct students’ misconceptions about AI, and thus fosters a more engaged learning experience.

## 7. Discussion

First, this study reveals that incorporating AI literacy into primary education curricula effectively enhances students’ AI knowledge and conceptual understanding of AI. The qualitative analysis of this study identifies several key areas of students’ AI conceptual understanding: 1) the comprehension and use of AI within the scope of digital literacy, 2) computational thinking, 3) AI ethics, 4) data literacy, and 5) AI thinking. These findings align with prior research, which shows that AI literacy includes the ability to use AI applications for digital literacy (Long & Magerko, 2020), developing computational thinking (Van Brummelen et al., 2021), cultivating AI ethics (Ali et al., 2019), thinking about and with AI (Ali et al., 2021; Yim, 2023, pp. 65–90), and considering AI’s ethical, social and environmental impact (Southworth et al., 2023).

More importantly, this study contributes the insight that AI thinking should be incorporated into AI literacy education in primary school contexts. Its findings highlight that AI thinking can be taught through arts-based pedagogy and align with those of Vazhayil et al. (2019) and Zeng (2013) that introducing AI thinking into AI literacy education in schools will enable students to go beyond their logic- and algorithm-based perspectives and expand their dialogic learning space (Wegerif & Major, 2023) to explore critical issues such as data injustice and AI ethics (Yim, 2023, pp. 65–90). By teaching AI thinking (the Big Idea Six) through an arts-based approach to collaborate with AI, students are enabled to expand their dialogic and creative learning space to consider the perspectives of humans and nonhumans in their AI literacy learning. By encouraging students to collaborate with their peers and AI learning tools, the arts-based approach may empower students to recognize the critical role of AI data and AI ethics as well as to enhance their potential in creative and AI thinking.

Second, contributing to findings from studies indicating that AI literacy can be taught to primary school students (Melsión et al., 2021; Shamir & Levin, 2021; Voulgari et al., 2021), this study demonstrates that, to a large extent, primary education curriculum with an arts-based pedagogical approach can contribute to the inclusiveness of AI literacy education across different genders and ages. Although this study draws upon a limited and unbalanced sample of students (25 participants in total, comprising 18 boys and 7 girls) from a single school, it serves as a valuable contribution, as it demonstrates the implementation of an arts-based pedagogical approach in primary school environments aimed at enhancing AI literacy.

In addition, previous studies have focused more on primary school students’ behavioral intentions (Chai, Lin, Jong, Dai, Chiu, & Huang, 2020; Chai et al., 2021) and readiness to learn AI (Chai, Lin, Jong, Dai, & Chiu, 2020; Dai et al., 2020). Their findings revealed that boys perceived themselves to be more motivated to learn AI than girls (Lin, Chai, et al., 2021). Since AI is viewed as a subdiscipline of computer engineering, the design of AI literacy education often involves the teaching of programming, scientific thinking, and mathematical algorithms, which, according to previous studies, might explain why male and female students react differently in learning AI. Similarly, according to numerous past studies of young students, boys outperform girls in other transdisciplinary subjects, e.g., in STEM learning tasks such as building blocks and robotic materials (Master et al., 2017; Sullivan & Bers, 2013) and spatial (Angeli & Valanides, 2020) and programming activities (Sullivan & Bers, 2016). However, the qualitative results of this study suggest that AI literacy courses that employ arts-based pedagogy enable students to develop their conceptual understanding of AI literacy, while the quantitative results indicate that students’ AI literacy knowledge is enhanced regardless of their gender and age.

Third, according to the perspectives of students and their parents, an arts-based approach not only boosts students’ motivation and engagement but is also well-suited for teaching AI literacy to young students. Previous studies have focused on constructivist methodologies for delivering AI literacy learning content in primary schools (Ali et al., 2019), such as project-based learning (Ho et al., 2019; Shamir & Levin, 2021), programming (Rodríguez-García et al., 2021; Shamir & Levin,



Fig. 14. AI artifacts made by one of the student participants, S3.

2021), and computer languages such as Scratch (Li & Song, 2020). However, there has been limited research on using arts-based pedagogy in primary education to enhance students' AI literacy knowledge (Yim & Su, 2024). This study contributes to the existing literature by demonstrating that arts-based pedagogy is age-appropriate and effective for teaching AI literacy.

Lastly, it is recognized that teachers may not be the only source of knowledge in the classroom. The findings of this study have demonstrated that the construction of knowledge is a socioculturally mediated process influenced by the physical tools and artifacts available to humans (Bakhtin, 2010; Vygotsky, 1979). The integration of AI literacy education through the use of AI learning tools can play such a mediating role in education. Mediation involves the use of tools to facilitate understanding (Vygotsky & Cole, 1978), which could be applied to learning about AI. In this study, students used physical art materials, drama and AI learning tools not only to interact with their environment but also to transform and potentially develop their own dialogic imagination and cognitive abilities.

## 8. Research implications

With an age-appropriate and inclusive approach, arts-based pedagogy can contribute to AI literacy in primary education. This study has demonstrated that using arts-based pedagogy can enhance students' knowledge of AI literacy and improve their conceptual understanding of AI. Incorporating AI thinking in primary school AI literacy curricula may expand students' dialogic learning space to create new ideas and allow them to consider human and nonhuman actors and address broader issues such as AI ethics and data justice. Therefore, researchers and educators are encouraged to use arts-based pedagogy to teach AI literacy to primary school students. Given that many students worldwide may not have access to computers, arts-based pedagogy may help narrow the digital divide in AI literacy learning.

Moreover, current AI educational tools often struggle to engage young students who lack a technical or computer science background (Yim & Su, 2024). Many existing AI learning platforms do not adequately support the development of students' thinking and creativity in AI, nor do they address fundamental AI concepts, data ethics, and societal impacts (Walter, 2024; Williams et al., 2024). To further enhance the quality of education, educators may consider integrating AI educational tools into their curriculum to foster AI literacy, and provide empowering learning experiences for students (Aravantinos et al., 2024). AI educational tools such as Doodlebot can facilitate human-robot interaction using multi-sensory support, thereby enhancing AI literacy and creativity development (Williams et al., 2024).

In addition, based on Vygotsky's social-cultural perspective, this study offers evidence to demonstrate the critical role of tools and technologies in mediating actions and promoting positive changes in AI literacy learning. Educational tools may offer a unique opportunity for educators to improve their instructional methods and create an equitable and productive classroom environment (Jacobs et al., 2024). However, there is a noticeable gap in the availability of age-appropriate AI learning tools that feature inclusive design and effectively introduce young students to foundational AI concepts while promoting their thinking abilities and creativity (Yim & Su, 2024). Therefore, this paper calls for educators and researchers to collaborate in designing and developing accessible AI literacy educational tools and software tailored to young students without programming expertise. In addition, future professional development programs may also include training on AI educational tools and arts-based teaching methods to equip teachers with the skills and confidence to implement these tools and strategies effectively in their classrooms.

## 9. Limitations

This paper has several limitations. First, its sample of primary school students may be biased since it examined only the test results of self-enrolled students who completed the entire course. The fact that these students voluntarily participated in the course may suggest that they were more interested in AI literacy learning than the average student. Second, the study has a small sample size, which may limit the scope of its findings. Also due to this small sample size, the gender and age group ratios of the study's participants are unequal. Caution should therefore be exercised before generalizing the study's findings to other contexts. Third, as indicated by the study's qualitative findings, students' representations of AI in their artworks were significantly influenced by their subjective perceptions, individual accounts, and cultural backgrounds. This paper reflects the experiences and cultural contexts of a small group of participants, limiting its applicability to larger and more diverse populations. In addition, the subjective nature of qualitative coding may introduce biases, despite efforts to ensure consistency. Fourth, while the quantitative analysis (i.e., knowledge assessment) suggests that the AI course had a significant effect, the study's ability to draw firm conclusions as to the extent of this effect is limited by the fact that it lacked: (i) a control group for comparison, (ii) validation of the assessment instrument, and (iii) test and re-test reliability. To address these concerns, future studies should incorporate control group or randomized control trial for isolation of the effect of AI courses by controlling for confounding variables, enabling a more comprehensive evaluation of its impact on AI knowledge acquisition. Furthermore, future design should employ content experts to review the instrument for content validity, construct instrument validation, check test and re-test reliability to ensure the reliability of the data collected or conduct additional analyses to improve the validity of this paper's findings. A larger sample size with participants from diverse backgrounds in terms of demographics and experience with AI should be considered to increase external validity of the study. Employing multiple coders and assessing inter-coder reliability can help reduce biases. Implementing more rigorous triangulation methods and a thorough review process for learning materials and tests will further enhance reliability and validity.

## 10. Future directions

Future research may explore the ways in which the arts-based approach could be used to promote creativity in AI literacy learning, as well as the development of a definition of AI literacy, an AI literacy framework, and assessment tools to evaluate AI literacy in primary school contexts. Additionally, studies could explore the influence of socioeconomic status and different cultural contexts on students in AI literacy education. To effectively implement AI literacy education in primary schools, it is crucial to explore educators' readiness to teach AI literacy, their challenges, and their professional development requirements. In addition, researchers and educators might consider adopting an arts-based approach for the inclusion of AI thinking in their AI literacy education curriculum to promote creative thinking and address issues such as AI ethics and data justice.

## Statements on open data, ethics, and conflict of interest

Ethical approval for this study was granted by the research supervisor and the Human Research Ethics Committee of the authors' university (dated August 02, 2023 and October 02, 2023). Informed consent was obtained from all participants, and their privacy rights were strictly upheld. The participant's personal information was anonymized to ensure confidentiality. They were informed that participation was voluntary and that they could withdraw from the study at any time and for any reason. There are no potential conflicts of interest in this study. The data supporting the findings have not been made publicly available; however, figures, surveys, and tests can be found in various locations:

Figs. 3–14 and Table 10, with excerpts provided in Appendices I and II.

### Funding information

This research study was supported by Wolfson College Travel and Research Grants, Year 2023, Reference TA 22104, at the University of Cambridge, United Kingdom.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### List of acronyms

Acronyms	Definition
AI	Artificial Intelligence
STEM	Science, Technology, Engineering, Mathematics
STEAM	Science, Technology, Engineering, Arts, Mathematics

### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.caeai.2024.100321>.

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### Acknowledgments

This paper is a contribution arising from the author's ongoing research study. The author appreciates the valuable guidance and support provided by Dr Eleanor Dare, Dr. Annouchka Bayley, Dr Morag Morrison-Helme, and the University of Cambridge to this study. The author also extends sincere gratitude to the independent researcher, Mr Mher Davtyan for his invaluable assistance with the coding work for this paper. His help is greatly appreciated. Thanks are extended to the primary school principal, teachers, students, and parents who participated in this project.

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**Iris Heung Yue Yim** is a Ph.D. student in the Faculty of Education at the University of Cambridge. Her research interests include artificial intelligence literacy, dialogic education, STEAM education, arts-based pedagogy, technologically enhanced pedagogic innovation, and early childhood and primary education.