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Artificial Intelligence (AI) literacy in early childhood education: an intervention study in Hong Kong

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ABSTRACT

The issue of Artificial Intelligence (AI) literacy is gaining popularity in the field of education. Most research on AI literacy has focused on primary, secondary, and higher education, and there has been limited examination of AI literacy programs in early childhood education. This study aimed to evaluate the impact of an eight-week AI literacy program on young children's AI literacy, AI-related creativity, and their perceptions of the AI4KG program. A total of 26 young children (average age of 4 years) enrolled in the program at a kindergarten in Hong Kong were the subjects of the study. The results indicated that (1) young children were capable of learning basic AI concepts and knowledge; (2) in terms of AI-related creativity, younger children were able to design a chatting robot via imagination, while older children created an AI robot to assist people in their drawings; (3) in regards to the children's perceptions of the AI4KG program, older children who enjoyed the activity were able to train AI, while younger children preferred to draw the future AI city and participate in the AI story activity. This study highlights the positive benefits of AI literacy education in preparing young children for an AI-driven future.

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Introduction

The growth of Artificial Intelligence (AI) has had a significant impact on human life, learning, and work. AI is defined as the field of study aimed at making computers capable of performing tasks that are currently in the domain of humans (Ertel, 2018). AI education and AI literacy are two crucial components of AI. AI education is seen as a driving factor for economic growth, the development of the future workforce, and global competitiveness (Druga et al., 2019). AI literacy, according to Long and Magerko (2020), refers to a set of skills and knowledge required for individuals to effectively communicate, work, and interact with other people and machines in a future dominated by AI. In the context of educating young children, AI literacy involves an understanding of basic AI concepts and the ability to use AI tools (Su, Ng, et al., 2023; Yang, 2022).

While AI literacy programs have been widely studied in primary, secondary, and higher education (Su et al., 2022; Su, Guo, et al., 2023), little attention has been paid to AI literacy programs for young children aged 3–5 years (Su, Ng, et al., 2023). This gap in research inspired the current study, which focuses on examining the AI literacy of children aged 3–5 years old in two classrooms at a Hong Kong public kindergarten.

The significance of this study lies in the growing use of AI technologies in our daily lives and the need for young children to understand these technologies, such as Siri and AI robots. Previous

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research has shown that AI literacy programs in kindergarten classrooms can have positive effects on young children's basic AI knowledge and inquiry skills (e.g. Kewalramani et al., 2021; Lin et al., 2020; Williams, Park, & Breazeal, 2019; Williams, Park, Oh, et al., 2019).

The aim of this study is to determine the impact of an eight-week AI literacy program intervention on kindergarteners' AI literacy, AI-related creativity, and perceptions of the AI4KG program (teaching AI to young children). This study is unique in filling two research gaps – investigating AI literacy in early childhood education (ECE) and exploring the effects of AI literacy programs on young children's creativity related to and perceptions of AI. The findings of this empirical research can contribute to the development of effective AI literacy programs for young children.

The benefits of teaching AI to young children have been widely documented by researchers. For example, improved AI literacy (Williams, Park, & Breazeal, 2019) and inquiry skills (Kewalramani et al., 2021) have been observed in young children who have undergone AI curriculum. In terms of basic AI literacy, Williams, Park, and Breazeal (2019) used knowledge assessments to evaluate children's understanding of AI concepts, such as knowledge-based systems, supervised machine learning, and generative music AI. The results showed that young children were able to comprehend these basic AI concepts after participating in AI activities (Williams, Park, & Breazeal, 2019). Additionally, playing with an AI robot has been found to enhance young children's inquiry skills, including creative inquiry, emotional inquiry, and collaborative inquiry skills (Kewalramani et al., 2021). The current study builds upon the existing research by evaluating the impact of AI literacy education in Hong Kong kindergarteners.

Theoretical framework: a model of teaching AI literacy in ECE

The level of AI literacy expected of students in early childhood education, primary, and secondary education varies greatly (Su et al., 2022). While young children are only expected to be familiar with fundamental AI concepts (e.g. Su & Zhong, 2022), primary and secondary students are required to have a deeper understanding of complex AI knowledge, including the ability to construct machine learning models (e.g. Shamir & Levin, 2022; Su et al., 2022).

In order to enhance children's understanding of AI literacy, scholars have created AI curriculums designed specifically for young children. As demonstrated by Kandlhofer et al. (2016), using a discovery-based and inquiry-based learning approach, and incorporating storytelling activities, fundamental AI concepts can be taught to kindergarten students. Similarly, Williams (2018) utilized learning activities such as drawing AI robots and playing Quick, Draw! to improve basic AI literacy among young children. Additionally, Su and Zhong (2022) developed an AI literacy framework for young children that encompasses AI knowledge, including an introduction to AI, speech recognition, and a discussion of AI biases. These studies highlight the numerous benefits of teaching AI to young children and demonstrate the significant value in researching AI curricula in kindergarten education.

In particular, Yang (2022) has proposed a model of using intelligent agents such as AI for Oceans, Teachable Machine, and Quick, Draw! to engage children in learning about AI literacy. Figure 1 highlights the role of AI educational tools, also known as intelligent agents, in the creation, testing, and demonstration of machine learning models. Machine learning models represent the process of training AI technologies. Utilizing these AI tools can aid young children in comprehending AI by making the concepts more accessible. The success in having children understand and utilize AI creatively relies on the intelligent agent's ability to carry out a transparent AI reasoning process, allowing children to gain a better understanding of AI practices (Yang, 2022).

The research context, objectives, and questions

Hong Kong was chosen as the location for this study because it is a hub of technological innovation and a leader in the development and implementation of AI technologies (Li, 2022). The ECE system in Hong Kong is well-established and highly regarded (Yang et al., 2017), making it an ideal location to

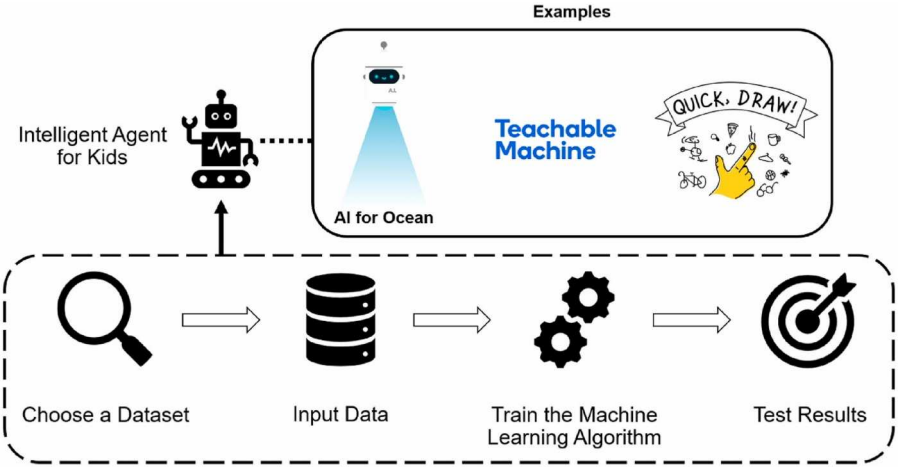


Figure 1. The model of using intelligent agents to demonstrate machine learning to young children © Weipeng Yang, 2022. Reproduced with permission.

conduct research on AI literacy in this field. Hong Kong researchers have started to pay more attention to the field of AI education for young children, as shown in recent publications (e.g. Su & Yang, 2022; Yang, 2022). Furthermore, the government of Hong Kong has been actively promoting the integration of AI technologies into various sectors, including education (HKSARG, 2023), making it a relevant and timely context for this study.

The two research objectives for this research study are to (1) investigate how AI can be effectively taught to kindergarten children; (2) examine how children learn AI and how it can enhance their AI literacy and AI-related creativity, namely understanding basic concepts of AI and machine learning. In this research paper, we will address the following research questions:

RQ1: To what extent does the AI4KG curriculum increase the participating children's understanding of AI literacy?

RQ2: To what extent does the AI4KG curriculum increase the participating children's AI-related creativity?

RQ3: What are the perceptions of children towards the AI4KG intervention?

Methods

The aim of the current study is to determine how an eight-week AI literacy program intervention affected young children's AI literacy, AI-related creativity, and perceptions of the AI4KG curriculum. This classroom-based study collected data from children aged 3–5 from a Hong Kong kindergarten. To better address the research questions, the researcher used a mixed-methods approach in this study, which includes quantitative and qualitative data. The quantitative instruments used were knowledge assessments. The qualitative instrument adopted was an interview protocol, which enabled researchers to understand children's perceptions of the AI literacy program designed for kindergarten education. To facilitate qualitative analysis, the qualitative data were coded and categorized.

Notably, the combination of quantitative and qualitative methods is important because it provides a more comprehensive and in-depth understanding of the research topic. Quantitative methods provide a numerical representation of data, which can be used to test hypotheses and make generalizations about the population (Creswell, 2014). Qualitative methods, on the other

hand, provide a rich and detailed description of the data, which can provide insights into the experiences and perspectives of the participants (Creswell, 2014).

Participants

Convenient sampling was used in this study to ensure the timeliness of this study. There were a total of 26 kindergarten children ($M_{age} = 4$ years old) in two classrooms at a Hong Kong public kindergarten. The kindergarten was selected due to its close proximity to the University of Hong Kong and the school teachers and principals' willingness to participate in the study. Within the sample, 100% of children had no prior experience in AI education.

Procedure

Over the course of eight weeks, two classrooms (morning class and afternoon class) finished an AI4KG curriculum. This course was taught by researchers and teachers – one researcher, three teachers, and two teaching assistants in each class. The AI4KG course was taught once a week and lasted approximately 30 min per module. Prior to implementing the AI4KG curriculum, 15 teachers from the kindergarten participated in a face-to-face teacher training workshop and were introduced to the AI4KG curriculum, including learning aims, teaching content, and teaching methods. The study was conducted from August to November of 2022.

Ethical approval

All procedures in this study were approved by The University of Hong Kong. Before participating in this study, participating kindergarten teachers, parents/guardians, and kindergarten children have signed a consent form. Parental consent was obtained for the children that participated in the study. The use of photographs and videos for this study was authorized, and the names of the participants were obscured in the video recordings.

The AI4KG curriculum

The AI4KG curriculum was delivered in eight 30-minute sessions in one Hong Kong public kindergarten as an after-school curriculum. The AI4KG program for the AI classes is a curriculum designed according to the three AI learning tools (i.e. AI for Oceans, Teachable Machine, and Quick, Draw!), as shown in Figure 1.

Table 1. The outline of AI curriculum design in kindergarten (Revised from Su & Zhong, 2022).

AI Knowledge	AI Skills	AI Attitude
KN1: Powerful ideas of AI: • AI is trained by humans. • Humans use big data to train AI. • AI is trained to solve problems and to help humans. • AI has its limitations.	SK1: Being able to identify AI applications in our daily lives.	AT1: Social Impact
KN2: Machine Learning	SK2: Using AI tools	AT2: Collaborate with AI
KN3: Potential ethical issues of using AI technologies	SK3: Solving problems collaboratively and with AI technologies when appropriate	

Su and Zhong (2022) developed an AI curriculum designed for early childhood, including three aspects, namely AI knowledge, AI skills, and AI attitudes. This study used this AI curriculum in the early childhood settings (Table 1).

The AI4KG curriculum was created based on Scott's (2007) curriculum design model, which emphasizes the four key components of learning goals, content, teaching methods, and assessment. The components of the AI4KG curriculum are as follows:

(a) Learning goals: What would we expect to be the learning outcomes as a result of participating in the implementation of this AI4KG curriculum?
(b) Content: What will we include from our AI4KG curriculum?
(c) Teaching approaches: What teaching approaches will we use to achieve these goals?
(d) Assessment: How will we know when we have achieved them?

The AI4KG curriculum includes two phases: fundamental phase and application phase (Table 2). The first phase is a foundational phase which mainly focuses on powerful ideas of AI, and potential ethical issues of using AI technologies. The second phase is the application phase which mainly focuses on machine Learning. Although each module covers a different topic of AI, the flow of the lessons is consistent. In addition to improving AI literacy, young children also improve AI creativity after the AI curriculum.

The three teaching methods used in the AI4KG curriculum are play-based learning, project-based learning, and story approach to integrated learning (SAIL). Play-based learning is simply the process of learning through play (Danniels & Pyle, 2018). This study designs two learning activities based on play-based learning. Story Approach to Integrated Learning (SAIL) is a storytelling curriculum and pedagogy that is commonly adopted by kindergartens in Hong Kong (Li, 2007). Project-based learning is "a student-driven, teacher-facilitated approach to learning" (Bell, 2010, p. 39).

Foundational phase

The purpose of how the robot learns activity (Module 1) is to enable kindergarten children to understand the principles of AI inference based on key data/features. The purpose of other learning activities (Module 2) is to enable kindergarten children to understand AI robots may not have encountered to illustrate that robots must continue to learn and improve. Children can improve their knowledge of AI robots through SAIL pedagogy in Module 3. For example, children read the picture book titled "Supervised Machine Learning for Kids" by Dr. Dhoot and answer a number of questions raised by the teacher, such as "What is the name of this story, please?", "Can you tell me what is supervised machine learning?", and "What machines are around you?".

Application phase

Due to a lack of strategies recommended for AI teaching and learning for children, project-based learning as a teaching strategy is proposed in Module 6 (Application phase) of the study.

Children understand the basic concepts of machine learning, how to use the AI tools (Quick, Draw!), and how to improve the accuracy of computer recognition of paintings in Module 4. Children can know how to distinguish between fish and garbage, what the ocean looks like, train fish with different characteristics, and choose a new word to teach AI in Module 5.Children can enhance problem-solving and communication skills after the AI curriculum in Module 6 and 7. For example, a machine learning activity (Recycling sorting activity) was designed using *Teachable Machine*. Children can know how to create a machine learning model and train their machine learning models with a teachable *machine*. Children will be asked to answer some questions about machine learning models. Module 8 summarized all learning modules.

Table 2. Activities in the AI4KG curriculum.

Phase	Module	Learning goals	Content (Learning activities)	Teaching approaches	Assessment
1st phase Foundational phase	1	Kindergarten children will be able to understand the principles of AI inference based on key data/features	AI robots	Play-based learning	1. AI literacy assessments; 2. AI-related creativity;
	2	Kindergarten children will be able to understand AI has its limitations	Is AI always right? Prejudice of AI	Play-based learning	
	3	Kindergarten children will be able to know AI robots in our daily life.	Story: AI robots	Story Approach to Integrated Learning (SAIL)	
2nd phase Application phase	4	Children will be able to understand how machine learning works with *Quick, Qraw!* and humans use big data to train AI.	Quick, Qraw!	Project-based learning	
	5	Children will be able to understand how machine learning works with *AI for Oceans,* AI is trained by humans, and AI is trained to solve problems and to help humans.	AI for Oceans	Project-based learning	
	6	Children will be able to create picture-based machine learning models with *Teachable Machine* and AI is trained by humans.	Teachable Machine	Project-based learning	
	7	Children will be able to create pose-based machine learning models with *Teachable Machine* and AI is trained by humans.	Teachable Machine	Project-based learning	
	8	Children will be able to summarize the basic AI concepts/knowledge and three Artificial Intelligence tools can be distinguished.	Conclusion Closing ceremony	/	

Data collection

Assessment, observation, and drawing were adopted to assess children's AI knowledge and skills, including AI and machine learning assessment and AI-related creativity and understand children's perceptions about AI literacy in kindergarten. Each of these evaluations was done independently. Considering that kindergarten children may not understand the words in the questions, all assessment items were read aloud by the researchers. Each participant spent 15–20 min on the post-test.

AI literacy assessment

AI literacy assessment was used to assess children's AI and machine learning knowledge at the end of the AI4KG curriculum. The AI and machine learning assessment includes five dimensions, namely AI for Oceans assessment, Quick, Draw! assessment, supervised machine learning, teachable machine assessment, and AI robots' assessment. For example, the question "*What food does the robot think is most like a tomato – Strawberry, banana, or milk?" was asked* (Williams, 2018). Three supervised machine learning questions were adopted from Williams (2018). Other questions were developed by researchers and ECE experts. The knowledge test included 18 multiple choice questions, with 1 point for correct answers and 0 for wrong answers. Inter-scorer reliability tests were high. A pre-test was not implemented because none of the children were introduced to AI before.

Evaluation of children's drawing

All AI4KG activities were observed and videotaped twice a week during two months. Kewalramani et al. (2021) used printing and drawing robots to assess children's creativity skills. This method was used in the current study. The researcher also communicated with children to deepen their understanding of AI robots and allowed them to explain their drawings in this study. The method adopted from Anning and Ring (2004) was used to evaluate how well kindergarten students are learning. Children in the last class were asked to draw pictures of their most memorable unit. They spent 20–30 min on the two tasks. They were then asked to describe their drawings, and put down their name, age and class on the back of the paper.

Data analysis

SPSS was used in this study. The data analysis method used in Williams (2018) was adopted. To analyze RQ1, Chi-square tests were used to compare the number of questions children correctly answered to the number of questions they should have correctly answered if they had merely guessed at random. There were 13 target assessment questions (19 questions total, but 6 of them were control questions). Statistical analysis shows that kindergarten children performed better than chance on 6 of the assessment questions.

In order to analyze the children's drawing data, this study adopted Emerson et al.'s (1995) coding method, which was used on the transcripts of kindergarten children's conversations and oral response during the AI4KG activities. Next, Strauss and Corbin (1990)'s coding methods were used to sort data into categories. The categories include different ages, 3, 4, and 5 years old. A senior researcher in the field of ECE worked as an inquiry auditor (Creswell, 2014) to ensure the validity of the qualitative data analysis and interpretation.

Results

We found that kindergarten children had neither prior experience with AI tools nor knowledge about AI concepts.

Table 3. Basic AI Knowledge Assessment.

Question	χ^2(df, N)	p	Cramer's φ
D1	$\chi^2(1,26) = 12.462$	0.000***	0.123
D2	$\chi^2(1,26) = 2.462$	0.117	0.210
D3	$\chi^2(1,26) = 7.538$	0.006**	0.158
D4	$\chi^2(1,26) = 5.538$	0.019*	0.175

Note: *$p < .05$, **$p < .01$, ***$p < .001$.

RQ1: To what extent does the AI4KG curriculum increase the participating children's understanding of AI literacy?

Basic AI knowledge assessment

The basic AI knowledge assessment includes four questions (Table 3). Most children can predict the transportation based on key data/characteristics (84.6%). However, some children do not know what AI knowledge is required to make this prediction (65.4%). It is possible that some younger children do not understand this activity or never took a taxi.

Researcher:	Let us play an interesting game first. Please see the screen. A riddle game, guess a mode of transportation. It's smaller than a minibus, larger than a bicycle, and comes equipped with a meter and a honking sound.
Child A (5 years old):	Taxi
Child B (3 years old):	Car
Researcher:	Why? How to guess?
Child A (5 years old):	Because … only taxis have a … meter. I think it's a taxi.
Child B (3 years old):	Car has a honking sound.
Researcher:	The correct answer to this question is taxi.
Child B (3 years old):	I never took a taxi.

AI for oceans assessment

The AI for Oceans assessment includes three questions (Table 4). Most children understood which situations enable AI robots to learn to classify more accurately. When presented with the options "data scarce" and "lots of data", few children know that AI robots can classify more accurately with "lots of data" presumably because they do not understand what data is.

Researcher: We play a new game. Please see the screen. An AI robot wants to classify a fish. In which of the following scenarios can an AI robot learn to classify more accurately?

Child C (4 years old):	Scenario 2 is a red fish. Scenario 1 is not a fish.
Child D (3 years old):	Scenario 2 is a fish.
Researcher:	Do you know what picture 1 is?
Child D (3 years old):	Not a fish. The shape … is not like … a fish.
Child C (4 years old):	Plastic … jar? I think I've … seen this.. at home.

Quick, draw! Assessment

Quick, Draw! Assessment includes three questions (Table 5). 76.9% of children answer the questions "if we want the computer to recognize a foot, then what can we draw?" and "how to make Quick, Draw recognize books?". It can be seen from this that children know how to identify

Table 4. AI for Ocean Assessment.

Question	χ^2(df,N)	p	Cramer's φ
E1	$\chi^2(1,26) = 5.538$	0.019*	0.175
E2	$\chi^2(1,26) = 18.615$	0.000***	0.693
E3	$\chi^2(1,26) = 7.538$	0.006**	0.377

Note: *$p < .05$, **$p < .01$, ***$p < .001$.

Table 5. Quick, Draw! Assessment.

Question	χ^2(df,N)	*p*	Cramer's φ
F1	$\chi^2(1,26) = 5.538$	0.019*	0.347
F2	$\chi^2(1,26) = 7.538$	0.006**	0.377
F3	$\chi^2(1,26) = 7.538$	0.006**	0.377

Note: *$p < .05$, **$p < .01$.

objects with Quick and draw software. However, some children do not remember the name of learning tools.

Supervised machine learning assessment

The supervised machine learning assessment includes three questions (Table 6). 84.6% of children answer the question about nearest neighbor associations correctly. Children struggle with the question about the AI robot that uses the nearest neighbor association to classify food, with only 53.8% of children answering this question correctly. Some children understand chocolate is unhealthy, so they think chocolate belongs to the bad group. This might have affected their accuracy in answering the questions.

Researcher:	Hello Children. Can you see this screen? You start the robot and put strawberries and tomatoes into the bad group. Which group will the robot think chocolate goes in? The good group or the bad group?
Child E (5 years old):	Bad group. Because … I think.. eating chocolate.. is not good, eating more … will be unhealthy for teeth.
Child F (4 years old):	Bad group. We cannot often eat chocolate. It's bad for our health.
Researcher:	Please see the screen again. Another question asks you to put ice cream in the good category and bananas in the bad category. What category will the robot put corn in? The good category or the bad category?
Child E (5 years old):	Corn and banana are the same color. I think it is the good category.
Child F (4 years old):	Corn is a good food.

Teachable machine assessment

Teachable machine assessment includes six questions (Table 7). The most challenging question is "what are the types of recyclables that can be sorted and separated from the recycling product?" In fact, many kindergarten children do not know the types of recycling. Most children understand AI robots can recognize gestures (84.6%). There are artificial intelligence robots in the Science and Technology Museum that can recognize children's postures, which may account for many children's ability to answer this question correctly.

Researcher:	Hello, children. Please look at this screen. Do you know how many types of recyclables can be sorted and separated from the recycling product?
Child G (3 years old):	Nine products.
Child H (5 years old):	Three
Researcher:	Why do you know three categories?
Child H (5 years old):	Paper, plastic, and mental.

Table 6. Supervised Machine Learning Assessment.

Question	χ^2(df,N)	*p*	Cramer's φ
G1	$\chi^2(1,26) = 12.642$	0.000***	0.123
G2	$\chi^2(1,26) = 12.642$	0.000***	0.123
G3	$\chi^2(1,26) = 0.154$	0.695	0.279

Note: ***$p < .001$.

Table 7: Teachable Machine Assessment

Question	χ^2(df,N)	p	Cramer's φ
H1	$\chi^2(1,26) = 0.154$	0.695	0.267
H2	$\chi^2(1,26) = 9.846$	0.002**	0.141
H3	$\chi^2(1,26) = 9.846$	0.002**	0.141
H4	$\chi^2(1,26) = 5.538$	0.019*	0.374
H5	$\chi^2(1,26) = 12.462$	0.000***	0.123
H6	$\chi^2(1,26) = 2.462$	0.117	0.306

Note: *$p < .05$, **$p < .01$, ***$p < .001$.

RQ2: To what extent does the AI4KG curriculum increase the participating children's AI-related creativity?

AI-related creativity

Children finished designing their own AI robot in class in the last session. Most children are four years old, with only one three-year-old and one five-year-old. The method adopted from Kewalramani et al. (2021) was used to assess children's creativity literacy. The children's worksheet was designed by a researcher. Results show that the older children designed AI robots that could interact to help others, but the younger children designed AI robots that were recreations of their AI robots (social robots). The youngest children (3 years old) design a robot that can chat with another robot but cannot help people (Figure 2). However, the older children (between 4 years old and 5 years old) designed an AI robot that can help people.

A three-year-old child:

> I design … an AI robot that can chat with other robots. (Child C)

Four-year-old children:

> I designed an AI robot that can help to sort trash with a robot, such as different colors that can sort different garbage. (Child H)

> I design an AI robot … which can help me dress up. This robot has many functions, including cutting my … hair, drying my hair, combing … my hair, etc. (Child S)

A five-year-old child:

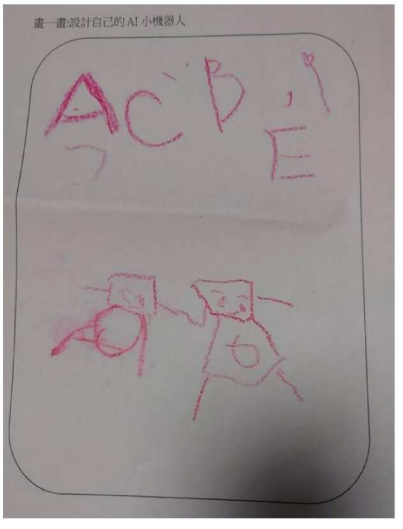
> I design an AI robot that can help … people make juice. (Child W)

RQ3: What are the perceptions of children towards the AI4KG intervention?

Children were asked to draw pictures of their most memorable activities and explain why they like this activity in the last concluding session (Figure 3). This method is frequently used to evaluate how well kindergarten students are learning (Anning & Ring, 2004). The researcher would like to know which AI4KG activities are the favorite and to understand kindergarten children's perceptions of the AI4KG intervention. It was found that older children enjoy the AI4KG activity that can train AI data, while younger children enjoyed drawing the future AI city and AI story activity, as elaborated below (Figure 2).

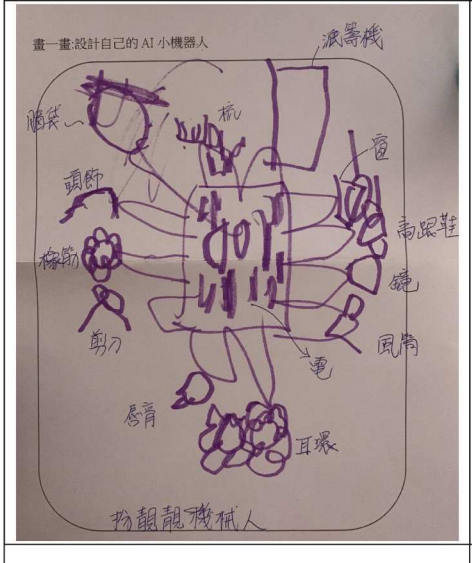
Five-year-old children:

Researcher:	Which AI4KG activities do you like most?
Child W:	I enjoy *AI for Oceans* activity.
Researcher:	Why?
Child W:	I learned how to train … AI data and I know that AI can't recognize it by itself.
Researcher:	Can you provide some examples for this activity?
Child W:	I need to train it as fish or rubbish and different colors of fish in the computer. And then AI can recognize which are fish and rubbish.
Researcher:	Do you enjoy this activity for learning AI?



3 years old: Two robots are chatting with each other

4 years old: Garbage sorting and recycling robot



4 years old: The AI robot that helps me dress up

5 years old: The AI robot can help us juice fruits.

Figure 2. AI robots designed by children.

Child W: Yes. This activity is very interesting for me. I have learned more about machine learning in this activity.

Four years old children:

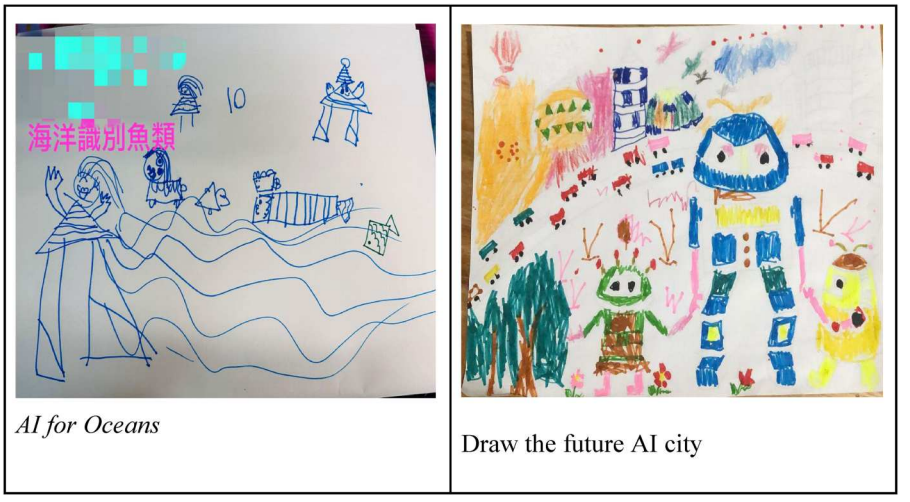


Figure 3. The memorable activities during the AI4KG intervention.

Researcher:	Which AI4KG activities do you like most?
Child C:	I enjoy drawing the future AI city activity.
Child K:	I enjoy the AI story activity.
Researcher:	Why?
Child C:	I usually hear my parents say that life is now in the age of AI, and many of the future societies will be intelligent. I wish that I have an AI robot in the future.
Child K:	I think that AI storytelling activity is very interesting, and I want to have that AI robot.
Researcher:	What kind of robots do you want to have? How can it help you?
Child K:	I want to have an AI robot that can pick me up from school and play with me.
Researcher:	Do you enjoy this activity for learning AI?
Child K:	Yes. I really enjoy listening to AI robot stories.
Child Ch:	Yes, I really like learning AI activity.

Discussion

The aim of the current study is to determine how an eight-week AI literacy program intervention affected kindergarteners' AI literacy. The AI4KG curriculum includes two phases: fundamental phase and application phase. The aim of the fundamental phase is to enable children to understand basic AI concepts/knowledge. The purpose of the application phase is to enable children to use AI tools and understand basic machine learning knowledge.

In terms of AI literacy assessment, we found that 92.3% of young children could identify the situations where it is easier for AI robots to perform classification tasks accurately and 53.8% of young children could not understand the types of recycling and the robot uses the nearest association to classify a food. This shows that young children only understand basic AI concepts/knowledge. The findings are consistent with Williams' (2018) study. Therefore, AI literacy in ECE and secondary students are very different (Su et al., 2022). Secondary school students can understand more complex knowledge (Ng et al., 2021). We suggest future researchers could design basic AI concepts assessment for young children. Furthermore, the majority of AI in ECE studies mainly evaluated young children's understanding of the fundamental AI concepts (Lin et al., 2020; Williams, Park, & Breazeal, 2019; Williams, Park, Oh, et al., 2019). For example, Williams, Park, and Breazeal (2019) and Williams, Park, Oh, et al. (2019) designed three AI concepts assessment to young children, including knowledge-based systems, supervised machine learning, and generative music AI. However, this study

designs a comprehensive AI literacy assessment to young children. Researchers may use these assessment items as a resource.

In terms of drawing pictures of their most memorable activities, this is an approach which is frequently adopted to evaluate how well young children are learning. It was not only used in Anning and Ring (2004) but also in the current study. Results show that older children enjoy the AI for Oceans activity in AI4KG curriculum while younger children enjoy drawing the future AI city and AI story activity presumably due to younger children's inability to use a computer.

The success of the AI4KG curriculum is supported by Yang's (2022) theoretical framework for AI literacy education. The curriculum employs story-based, play-based, and project-based teaching methods to actively engage children in AI-related activities. These methods are exemplified by AI applications such as AI for Oceans, Teachable Machine, and Quick, Draw!, which act as intelligent agents to demonstrate the reasoning process behind AI and help children better understand AI practices, as shown in Figure 1.

Implications

AI literacy in ECE is a new topic. Most AI in ECE studies was conducted in the USA (Williams, Park, Oh, et al., 2019; Lin et al., 2020). Many researchers know little about how to design AI curriculum for young children. This is the first study about AI literacy in Asia, especially in Hong Kong. It provides some examples (curriculum design, activities, and teaching approaches) for educators and researchers as a reference.

Recently, most AI literacy in ECE studies used AI tools, namely PopBots and Zhorai (Lin et al., 2020; Williams, Park, Oh, et al., 2019). However, these learning tools are not open to the public, which limits children's access. This study used three AI learning tools which the public can access for free (Yang, 2022). Not only all kindergarten children given an opportunity to acquire basic AI knowledge, but also given suitable learning AI opportunity. Findings showed that enhanced young children's understanding of basic AI concepts and knowledge through using AI tools.

In terms of AI literacy assessment, this seems to be no comprehensive assessment methods to assess children's AI literacy, including basic knowledge and the basic knowledge of AI learning tools, namely basic AI knowledge, AI for Oceans, Quick, Draw!, Teachable Machine, and supervised machine learning. Some studies used knowledge assessment to assess children's basic AI concepts or machine learning knowledge (Lin et al., 2020; Williams, Park, Oh, et al., 2019). This study used a comprehensive assessment questionnaire to assess children's AI literacy, which filled the gaps in the extant literature in this field of research.

This paper also provides AI teachers with lesson plans, including learning goals, learning activities, and teaching methods. Results showed that play-based learning, project-based learning, and story approach to integrated learning (SAIL) are suitable learning methods. Future AI teachers can design some questions in AI story activity to help children better understand AI robots. For example, having shown children some pictures of different AI robots that they might have seen in daily life, they can be invited to share what they know about these robots, such as their functions.

Although there are currently no policies stating that AI education is compulsory for kindergarteners, it is recommended that AI literacy programs be incorporated into the kindergarten curriculum since children are found to be able to acquire some basic AI knowledge at a young age. Policymakers may consider implementing AI education in kindergartens with the help of the AI4KG program, which not only enhanced children's basic AI knowledge, but also their creativity skills.

Future research directions

This paper offers some assessment methods as a reference for researchers. While most kindergarten children can understand basic AI knowledge, as evidenced by their awareness of factors affecting AI robots' ability to classify objects accurately, they cannot understand complex notions, such as data.

They also enjoy drawing and story-telling activities. Therefore, future researchers could develop an AI curriculum which presents AI concepts in a simple manner through the incorporation of drawing and story-telling elements. Also, more validity and reliability information should be obtained for the children's AI literacy tests or assessments. Moreover, this study was conducted in kindergarten settings, which differ from informal learning settings such as home environments. Future studies can promote similar AI literacy learning opportunities in home environments and other informal learning settings to evaluate the impacts on children.

Conclusion and limitations

The purpose of this research was to examine the impact of an eight-week AI4KG program on kindergarten children's AI literacy. 26 kindergarten students participated in the study, and the results showed that they were able to learn basic AI knowledge. The study found that the 5-year-old children particularly enjoyed the AI data training activity, while the 3 and 4-year-old children preferred drawing future AI cities and creating AI stories.

This paper provides some useful information for researchers regarding AI curriculum design and assessment methods. However, it is important to note the two limitations of this study. Firstly, the data was only collected through assessments and observations, and future research could benefit from incorporating teacher interviews to gather their perspectives on the AI4KG program. Secondly, the sample size of 26 participants is relatively small, and it would be valuable to see if larger studies yield similar results. Lastly, it is important to note that convenient sampling may result in a biased sample and may not be representative of the population as a whole, so caution should be used when interpreting the results of this study.

In conclusion, this study highlights the potential for AI literacy programs to positively impact young children's AI literacy and provide suggestions for further research in this field.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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