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Artificial Intelligence (AI) in early childhood education: Curriculum design and future directions

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A R T I C L E I N F O

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A B S T R A C T

With the rapid technological development of society brought on by Artificial Intelligence (AI), the demand for AI-literate workers will increase in the future. It is critical to develop the next generation's AI competencies and educate them about how to work with and use AI. Previous studies on AI were predominantly focused on secondary and university education; however, research on the Artificial Intelligence curriculum in early childhood education is scarce. Due to the lack of conformity on the standardisation of AI curriculum for early childhood education, this study examines the AI curriculum for kindergarten children using the framework which consists of four key components, including (1) aims, goals, objectives, or declarations of outcome, (2) subject matter, domains, or content, (3) methods or procedure, (4) evaluation and assessment. We recommend that AI literacy be achieved by three competencies: AI Knowledge, AI Skill, and AI Attitude. The employment of a social robot as a learning companion and programmable artifact was proven to be helpful in assisting young children in grasping AI principles. We also discovered which teaching methods had the most greatest influence on students' learning. We recommend problem-based learning for future AI education based on the findings.

1. Introduction

Artificial intelligence (AI) was defined as "the science and engineering of creating intelligent machines'' (McCarthy, 2007, p. 2). Artificial intelligence (AI) is a branch of computer science that combines machine learning, algorithm development, and natural language processing (Akgun & Greenhow, 2021). The importance of AI development has mostly been highlighted in secondary and higher education (Su et al., 2022), but seldom was conducted in kindergarten level. As the younger generation now have robots in their homes and intelligent agents in their pockets, children within their first years of life can interact with tablets and toys that have magnitudes more computing power than personal computers just a decade ago (Williams, Park, Oh, & Breazeal, 2019). Recently, there has been an increase in the number of studies on early childhood AI education (Kewalramani et al., 2021; Prentzas, 2013; Su & Yang, 2022; Williams, Park, Oh, & Breazeal, 2019). For example, teach children AI concepts using PopBots, knowledge-based systems, supervised machine learning, and generative AI (Williams, Park, Oh, & Breazeal, 2019; Williams, Park, & Breazeal, 2019). However, there are insufficient studies on AI curricula in early childhood education in the existing literature.(e.g., Williams, Park, Oh, & Breazeal, 2019; Williams, Park, & Breazeal, 2019)..

AI in kindergarten and AI in secondary and higher education are very different. AI in kindergarten mainly focuses on basic concepts and simple AI activities (e.g., drawing concept maps and AI framing). However, AI in secondary and higher education mainly focuses on programing (e.g., Scratch and Google Teachable Machine), and complex concepts. Kindergarten children need to learn AI. There are many benefits for kindergarten children to learn AI. For example, children enhanced computational thinking skills and problem solving skills through AI activities (Su & Yang, 2022; Williams, Park, Oh, & Breazeal, 2019; Kandlhofer et al., 2016) and improved AI knowledge (Williams, Park, Oh, & Breazeal, 2019) through AI curriculum. Furthermore, young children playing with the AI robot improved several inquiry literacy skills (i.e., creative inquiry, emotional inquiry and collaborative inquiry skills) (Kewalramani et al., 2021). Therefore, we strongly suggest that kindergarten children learn AI.

The term curriculum refers to "the sum of all direct and indirect experiences, activities, and events that occur within a setting meant to encourage children's learning and development" (Ministry of Education, 1996, p. 10). A curriculum can be structured into four dimensions: goals or objectives, content or subject matter, methods or procedures, and evaluation and assessment (Scott, 2008). Many academics have

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confirmed that high-quality early childhood education has a positive impact on children's educational achievement or children-teacher relationships (Muijs et al., 2004; Wesley & Buysse, 2010; Egert et al., 2018). To ensure high-quality early childhood education, governments and policymakers internationally have started to integrate computational thinking into the curriculum from the earliest grades. A number of studies have proved that using coding or programming apps can help cultivate children's computational thinking skills (Papadakis, 2021, 2022; Weintrop & Wilensky, 2015) and contribute to reasoning and communicating in an ever-increasingly digital world (Kafai & Burke, 2014). Yasmin Kafai and Quinn Burke (2014) describe the picture of contemporary computational participation: students who code not for the single purpose of coding, but to create games, stories, and animations to share; more and more young people participate in programming communities; challenges arise in the practices and ethical use of programming; and students move beyond stationary screens to programmable toys, tools, and textiles. While early AI studies are beneficial for kids cognitively, intellectually, and socially, we discovered that there are no strategies recommended for AI teaching and learning for kids. Therefore, we recommend using problem-based learning as a teaching strategy in group projects. Problem-based learning can enhance critical thinking, problem-solving, and cooperation skills. Therefore, there is an urgent need to systematically design early AI curriculum, teaching methods, assessment suggestions, and future directions.

2. Background

2.1. Existing guidelines for AI education

As artificial intelligence (AI) becomes more prevalent in society, there will be a greater demand for AI-literate workers in the future. As our society faces major public policy issues involving AI technologies, informed citizens are required to comprehend the fundamentals of AI. To prepare children with competencies to face the rapidly transforming and tech-driven world and help them ensure their employability and career potential in the future (Preface, 2021), children must be sufficiently educated to work with and use AI (Touretzky et al., 2017).

Countries such as China, the United Kingdom, Thailand, Korea, and the European Union are making strides in AI education to standardize what students should learn at various levels. Many groups have created criteria for teaching AI to students in grades K through 12. The Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA) launched a joint working group in May 2018 to create national guidelines for teaching artificial intelligence to K-12 students (AAAI, 2018). In line with the CSTA's national standards for K-12 computer education (CSTA, 2017), the AI for K-12 recommendations (ai4k12.org) established what students in each grade band should know about artificial intelligence, machine learning, and robotics. The working group provided an online resource directory for teachers to locate AI-related videos, demo software, and activity descriptions, which they may include into their lesson plans. Other organizations, such as AI4ALL (-4-all.org) and the International Society for Technology in Education (ISTE), have noticed these issues and are addressing them (Baloch et al., 2018; ISTE, 2018). Academic debates on the definitions and components of AI literacy, on the other hand, are still ongoing (Kim et al., 2021).

Among the organizations, AI4K12 proposed the Five Big Ideas framework, which includes Perception, Representation and Reasoning, Learning, Natural Interaction, and Societal Impact, to cover the breadth of the area and make it approachable for teachers. The framework not only includes definitions and examples for each principle, but it also goes into greater detail about what K12 students should perform in each category. For example, the first concept is Perception, which refers to the process of extracting meaning from sensory inputs. It contains speech recognition, computer vision (e.g., object detection, face recognition, license plate readers, and scene understanding), and other forms of perception (e.g., music recognition, or interpreting sonar, radar, or LIDAR data). The framework also explains what K-12 students must do in the category of concepts. Students in grades K-2, for example, learn to recognize sensors on computers, robotics, and smart appliances, as well as engage with intelligent agents like Alexa or Siri. Students in grades 3–5 must explain how sensor inputs are translated to analog or digital signals, demonstrate a computer perception constraint, and create an application using perception (possibly with Scratch plugins, or Calypso). Students in grades 6–8 must explain how sensor constraints affect computer perception, describe how perception systems use numerous algorithms and many sensors, and create an application that uses multiple sensors and forms of perception (possibly with Scratch plugins, or Calypso). Students in grades 9–12 must describe the domain knowledge that underpins various forms of computer perception and demonstrate speech recognition difficulty while dealing with homophones and other types of ambiguity. The framework provides considerations for students' activities as well as relevant learning tools to help AI education. However, this paradigm is primarily focused on K12 AI education, with grade 2 levels as the minimal age range. Though pupils are encouraged to consider STEM occupations at an early age, AI curriculum design for kindergarten students was limited. There is a compelling need to investigate AI curricula for kindergarten students in a methodical manner.

2.2. AI curriculum for kindergarten

AI education goes beyond computational thinking, it explores how computers sense, think, act, learn, make decisions, create, perceive, and make sense of things. Younger children, who are concrete thinkers and active learners, especially benefit from hands-on approaches to learn STEM (William et al., 2019). It is believed that learners as young as 3-years old could be fit to start exploring AI in a simple and foundational manner (Preface, 2021). Kids are rapid and curious learners. Learning AI can be a very fun and rewarding educational experience with the right approach and resources (Preface, 2021). To equip kindergarten children with AI literacy, Kim et al. (2021) considered the curriculum development for early childhood education from three perspectives: 1) help children identify AI technologies in their daily lives, 2) equip them with programming skills to use the technology in real-world situations, and 3) be aware of potential ethical issues of using AI technologies. They thus summarized three competencies to achieve AI literacy: AI Knowledge, AI Skill, and AI Attitude.

2.2.1. AI knowledge

The AI Knowledge aims to help students understand the fundamental ideas of artificial intelligence (Kim et al., 2021). AI Knowledge competency is categorized into five clusters, including, 'Definitions and Types of AI', 'Problem-Solving and Search', 'Reasoning', 'Data and Machine Learning', and 'Applications'. 'Definition and Types of AI' refers to the understanding of what qualities distinguish AI-based systems from algorithm-based systems. The term 'Problem-Solving and Search' denotes a familiarity with search techniques. 'Reasoning' is the study of using a computing model to simulate human logical reasoning processes. 'Data and Machine Learning' indicates understanding machine learning algorithms that detect patterns in data. The 'Applications' subcategory is knowledge in various AI application domains, such as computer vision, speech recognition, and machine translation, whose contents are closely linked to the curriculum's purpose of fostering AI literacy. The 'Applications' activities are designed to allow participants to try with and learn about common AI technologies like voice recognition and optical text recognition. Students can use AI applications based on their grasp of technology after seeing them in real-world circumstances (see Fig. 1).

2.2.2. AI skill

Students with AI skill competency are able to think computationally based on their programming abilities (Kim et al., 2021). 'Using AI Tools'

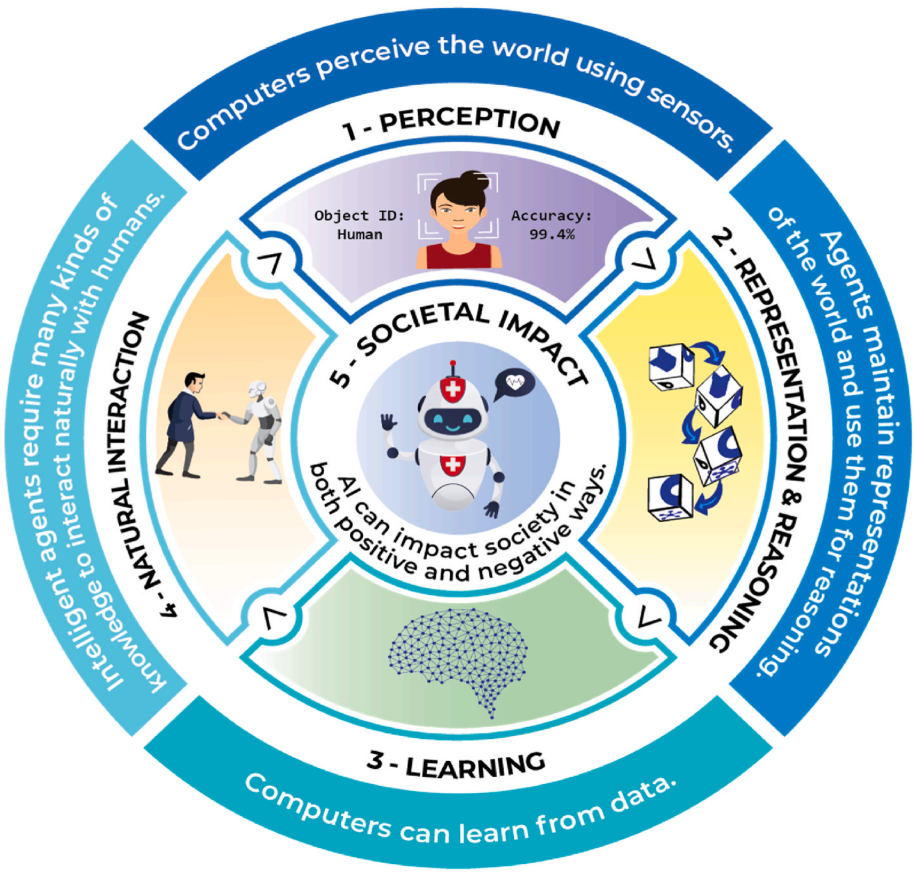


Fig. 1. *AI4K12 proposed the Five Big Ideas framework.*

and 'Computational Thinking and Programming' are two AI skill competencies. 'Using AI Tools' denotes the ability to solve problems using proper AI tools. The term 'Computational Thinking and Programming' refers to the ability to build simple AI applications, with the goal of improving students' computational thinking. Kim et al. (2021) developed an AI competence framework of ReadyAI to promote computational thinking and programming. According to Wing (2006), computational thinking indicates a student's capacity to solve issues, build systems, and understand human behaviour based on computer science. Computational Thinking stresses thinking at numerous abstraction levels in order to develop a student's critical analytical skills in a world where computers are everywhere. Since computer science covers AI, computational thinking is considered to be a necessary skill for a student to acquire in order to become AI literate (Kim et al., 2021).

2.2.3. AI attitude

AI Attitude competency improves students' ability to consider all aspects of AI in society collectively. Kim et al. (2021) believed that AI Attitude includes 'Social Impact' and 'Collaborate with AI'. The AI Attitude competency assesses students' ability to recognize both the positive and negative effects of AI on society, as well as their critical viewpoint on AI use. Citizens who are AI literate should be able to use AI for the greater good. While AI is a driving force for innovation, it also poses a threat to children's rights, such as privacy, safety, and security. However, children are only mentioned briefly in most AI initiatives and guidelines (AI for children, 2022) and the impact of AI systems on children and their rights receives little consideration. This is especially troublesome because youngsters are less able to completely comprehend the implications of AI technology and frequently lack the means to express their views, as well as the right advocates to back them up. Children frequently lack the resources to respond to incidents of bias or to correct any data misinterpretations (AI for children, 2022). The incorporation of AI into the human decision-making process raises ethical concerns about its application, such as a commercial gender-biased face classifier Buolamwini and Gebru (2018) and word embedding with encoded racial stereotypes (Manzini et al., 2019). For students to reflect on themselves and acknowledge different points of view, a balanced view of the conflicting ethical issues of AI is required. In this regard, AI literacy competencies should ensure that students have a clear understanding of AI (Wong et al., 2020).

2.3. Tools and resources for AI at the kindergarten level

In order to promote students and instructors in grades K-12 to explore AI and appreciate the fundamental ideas, they are encouraged to use auxiliary tools to help understand it. There has been a recent burst of tools and techniques that make artificial intelligence (AI) more accessible to younger students. Touretzky et al. (2017) identified a variety of tools and useful resources for both students and teachers to engage in AI education, which are listed as follows:

- Cognimates (Druga et al., 2018) is a Scratch add-on that gives users access to APIs for voice production, speech recognition, text classification, object identification, and robot control. https://cognimates.me
- eCraft2Learn (Kahn & Winters, 2017) offers similar extensions for the Snap! language, a Scratch variant. https://ecraft2learn.github.io/ai/
- Machine Learning for Kids is another website that offers online demonstrations in which kids can train classifiers using web applications or Scratch extensions. https://machinelearningforkids.co.uk/
- The Cozmo robot is a low-cost mobile manipulator with built-in computer vision that includes object and custom marker detection,

face recognition, object handling, path planning, and speech production.

- Calypso for Cozmo (Touretzky, 2017) is a rule-based visual programming language for Cozmo that includes speech recognition, landmark-based navigation, a visible global map, and state machine programming capabilities. https://Calypso.software
- Google has launched a number of free “AI experiments,” including “Teachable Machine” and “QuickDraw,” which uses a neural net to identify what you’re sketching. https://experiments.withgoogle.com/collection/ai
- Google’s AIY (“AI and You”) vision and voice kits enable low-cost image and speech recognition based on the Raspberry Pi Zero. The voice kit links to the cloud-based Google Assistant, while the vision kit employs a neural network classifier.
- TensorFlow Playground is a graphical application that allows high school and undergraduate students to experiment with neural networks and backpropagation learning (Medium, 2022). https://playground.tensorflow.org

In addition to these tools and platforms, Weintrop et al. (2016) drew on three resources for creation and validation of the taxonomy of computational thinking in mathematics and science, including (1) educational activities in mathematics and science, (2) existing concept inventories and standards documents, and (3) interviews with mathematicians and science. Weintrop et al. (2016) further broke the taxonomy into four categories, 1) involving data practices (i.e., collecting, creating, manipulating, analyzing, and visualizing data), 2) modeling and simulation practices (i.e., using models to understand a concept, find and test solutions, and assessing, designing, and constructing computational models), 3) computational problem solving practices (i.e., preparing problems for computational solutions, programming, choosing effective computational tools, assessing different solutions, developing modular computational solutions, creating computational abstractions, and troubleshooting and debugging), and 4) systematic thinking (i.e., investigating a complex system as a whole, understanding the relationship within a system, thinking in levels, communicating information about a system, defining systems and managing complexity). This study offered a range of useful resources for AI learning, which not only contributed to building on the reciprocal relationship for learning between computational thinking and mathematics and science domains, but also helped address practical concerns in the fields. Moreover, Lin and Weintrop (2021) found a number of computer science curricula teaching with block-based programming (BBP) environments, such as Exploring Computer Science, Scratch Encore, the Beauty and Joy of Computing, and the suite of materials developed and shared by code.org in both formal and informal contexts. While looking at the use of block-based and text-based programming tools in high-school introductory programming contexts, Weintrop and Wilensky (2015) discovered that older students learn in a formal setting, which is quite distinct from the younger audience and informal settings. The study indicated that students attribute the ease-of-use of tools largely to visual features of the environment, including the graphical presentation of the blocks, the drag-and-drop mechanism for authoring programs, and the ease of browsing the available set of blocks to figure out what commands to include in the program. The study also showed that students’ motivation and interest further influences students’ perceptions and their use of tools. Knowing the factors that impact students’ use of programming tools helps better inform instructors, researchers, and course designers in terms of what is working, what aspects of their design we might want to modify, and what features of these tools we might want to introduce to young learners.

Based on the current literature, we discovered that previous research mainly was focused on the general tools for AI learning (e.g., Touretzky et al., 2019; Kafai & Burke, 2014), using AI for specific subject education (Weintrop et al., 2016; Hasib et al., 2022), or use of programming tools in secondary education (Lin & Weintrop, 2021). These studies offered useful ramifications for the proper use of AI tools, characteristics of learners at different ages, as well as various factors that might impact quality of learning in K-12 settings. The existing AI preschool curriculum focuses on teaching children AI concepts (i.e., knowledge-based systems, supervised machine learning, and generative AI) using PopBots) (Williams et al., 2019a, 2019b; Williams, Park, Oh, & Breazeal, 2019), but lacks comprehensive and in-depth investigation on its standardisation of AI curriculum for kids. Therefore, it is critical to study AI curricula’ design, implementation, and evaluation for early childhood education. This study aims to fill a gap in the AI curriculum in ECE and improve AI curriculum in a variety of ways in terms of research design and teaching methods, evaluation, and future directions for researchers and educators.

3. Research objectives and research questions

This study not only contributes to a holistic understanding of objectives, contents, specific methods, as well as assessments on how to develop effective AI courses for children, but also specifies the conformity in the standardisation of AI curriculum for instructors in early childhood education.

This study has two research objectives, which aim to develop an AI curriculum framework for early childhood education and explore relevant activities that can demonstrate the AI curriculum framework. Therefore, we proposed four research questions that are well worth investigating.

RQ1. What content should be included in early AI teaching units?

RQ2. What are the teaching methods and learning design that should be included in early AI teaching units?

RQ3. What are assessment suggestions in early AI curriculum studies?

RQ4. What are future directions relating to early AI curriculum studies?

4. Framework for designing AI curriculum

There were a variety of frameworks in support of curriculum development. Each framework is linked to different ideologies and thinking about curriculum. For instance, sociocultural learning emphasizes society and people as key dimensions of learning (Smith, 1996); instrumentalism aims to justify curriculum in terms of what virtues and experiences children should have (Neyland, 2005), scientific curriculum stresses the application of scientific methods to study curriculum (Bobbitt, 2013), and many other ideologies to develop curriculum. However, these curriculum models are difficult to categorize and use due to different needs, various cognitive levels of learners, as well as the change of contexts. There is a necessity to develop a more applicable framework for AI curriculum design for early children education. This study intends to propose the framework developed by Scott (2008) for effective guiding the design and implementation of AI curriculum for the early childhood education (Fig. 2). This framework can be applied to any teaching and learning setting from preschool to university education. The framework includes four key dimensions: (1) aims, goals, objectives, or declarations of outcome, (2) subject matter, domains, or content, (3) methods or procedure, (4) evaluation and assessment (McLachlan, Fleer, & Edwards, 2018).

5. Curriculum design, assessment and implementation for AI in early childhood education

5.1. Content and activities

5.1.1. Curriculum design

The curriculum design includes four modules and lesson objectives. Some researchers teach AI concepts (i.e., knowledge-based systems,

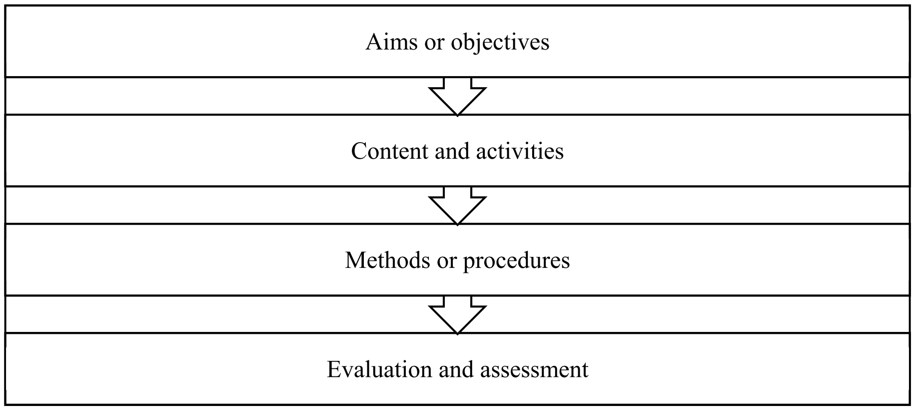


Fig. 2. Four elements framework of AI curriculum design for the kindergarten classroom.

supervised machine learning, and generative AI) using PopBots (Williams, Park, Oh, & Breazeal, 2019). The advantages of AI education include improving children's two skills, such as problem solving and critical thinking skills. More details of the early AI curriculum design can be found in Table 1.

5.2. Classroom materials

In addition to lesson plans, lecture slides (PPT), student workbooks (worksheets), and teacher's guides (guidebooks), the proposed early AI curriculum are included in a classroom material package. The lesson plan in each module includes lesson objectives, material needs, knowledge, activities, and assessment suggestion rubric. Teachers who are unfamiliar with AI concepts will benefit from the teacher's guide which helps reduce their workload even more (Sabuncuoglu, 2020). The student workbook is an educational material that includes components that support learning and assist in ensuring students' knowledge and ability in accordance with the acquisitions stated in teaching programs (Ulu Kalin, 2017).

5.3. Curriculum theme

Table 1 shows the proposed AI curriculum content, including lesson plans, curriculum and activities that are most appropriate for children in grades K3-5 (5–7 years old). This course is suitable for all children at different levels. The early curriculum ranged from easy to difficult. In order to enhance children's thinking and problem-solving skills. The course includes four modules, four activities, and one project.

5.3.1. Considerations for module design

The following considerations guide the design of all early AI curriculum modules. The content of each module can enhance children's several competencies skills. In addition to teaching AI knowledge, we also propose some AI activities for children. These activities can enhance children's thinking, creativity, and problem solving skills. The activities for developing AI skill competency are designed to give students hands-on experience with AI technologies in their daily lives.

Table 1
The outline of AI curriculum design in ECE.

AI Knowledge	AI Skills	AI Attitudes
K1: Definition of AI & examples of AI	S1: Using AI tools	A1: Social impact
K2: The Five Big Ideas in AI	S2: Computational thinking and programming	A2: Collaborate with AI
K3: Machine Learning	S3: Critical thinking	
K4: Applications	S4: Problem solving	
K5: AI ethics		

5.4. The structure of the early AI curriculum

Each module of the early AI curriculum consists of two lessons. Each of the modules is designed to incorporate at least one more AI activity. Although each module covers a different topic of AI, the flow of the lessons is consistent, as shown in Table 2.

5.4.1. Module 1: introduction to AI

Children are introduced to the fundamental concepts of artificial intelligence in the first module (Table 3). The learning objective of the first module is to understand the basic knowledge of AI, such as concepts, what is AI, examples of AI in daily life, and the five big ideas in AI. The AI4K12 project aims to teach AI at the K-12 level in the United States (Sentance, 2022). The AI4K12 team has matched their AI teaching concept with the CSTA computer science education requirements (ISAST, 2021). Five key AI ideas were offered by AIK12 include perception, representation & reasoning, learning, human-AI interaction, and societal impact (AI4K12, 2021), as shown in Table 4. A number of professional websites (AI4K12) and professional AI education company (ReadyAI) mentioned that five big ideas are suitable for K2-5 children to learn (AI4K12, 2020; ReadyAI, 2022). Ready AI suggests the series book "AI + Me: Big Idea" suitable for K-2 students to read (ReadyAI, 2022). The first activity children will draw is what AI is already used in our everyday life and share the ideas. This activity helps children gain a better understanding of artificial intelligence.

5.4.2. Module 2: machine learning

Children are introduced to the fundamental concepts of machine learning in the second module (Table 5). The learning objective of the second module is to understand the machine learning concept, working principles of machine learning, and machine learning examples. Machine learning is a growing field of computational algorithms that aim to mimic human intelligence by learning from their surroundings (EI Naqa & Murphy, 2015). Machine learning is about training an algorithm, and to train an algorithm, one needs a neural network, a collection of algorithms inspired by biological neural networks and modeled after the human brain, which is made up of individual neurons connected to one another (iDTeach, 2020). Examples of machine learning include smart cars, navigating the complexities of web search and automatic recommendation systems. The second activity includes children playing with Google's Quick Draw! and sharing their ideas. This activity helps children gain a better understanding of machine learning. Some researchers mentioned that Google's Quick Draw! is suitable for children to learn (Wang et al., 2019).

5.4.3. Module 3: Artificial Intelligence Techniques

Children are introduced to the Artificial Intelligence Techniques in the third module (Table 6). AI techniques include facial recognition,

Table 2
The guideline of Lesson and learning objectives.

Module	Lesson	Time	Lesson goals	Main points	Outline
Module 1 Introduction to AI	1	30 mins	Children will be able to understand the definition of AI	What is AI?	K1 AI
	2	30 mins	Understand the fundamentals of the Five Big Ideas	Five Big Ideas (Perception, Representation & Reasoning, Learning, Human-AI Interaction, and Societal Impact)	K2
	Activity 1 Draw AI already used in our everyday life	20 mins	Children will be able to know what AI has been already used in our everyday life	How is AI being used in our daily lives	K1 S4
Module 2 Machine Learning	1	30 mins	Children will be able to understand what is machine learning and how machine learning works	What is machine learning How machine learning works	K3
	Activity 2 Google's Quick Draw!	50 mins	Children will be able to understand how machine learning works	How machine learning works using Google's Quick Draw!	S1 S2
Module 3 Speech Recognition	1	30 mins	Children will be able to know what is speech recognition	Artificial intelligence applications	K4 AI
	Activity 3 PictoBlox	50 mins	Children will be able to learn how to use the Speech Recognition to control the appliances with voice commands.	Learn AI and machine learning	S1 S2
Module 4 Flaws and biases of AI	1	40 mins	Children will be able to learn the flaws and biases of AI	Learn the flaws and biases of AI	K5
	Activity 4 Draw AI helping humanity	20 mins	Children will be able to learn how to use AI helping humanity	AI helping humanity	A2
	Activity 5 Draw concept map	20 mins	Children will be able to summarize the key points	Summary of AI, machine learning knowledge	K1–K5 S3
Project	Smart Plant	1h	Children will be able to learn programming knowledge	Programming knowledge	S2 S4

Table 3
Lesson plan for Module one (Part A).

Lesson 1: Introduction to AI (Part A)
Level 1 Grade: K3-5 (5–7 years old) Classroom time ● 30 mins introduction ● 10 mins summary Learning objectives ● Understand that AI concept ● Recognize that what is AI Material needs AI pictures Knowledge (30 mins) ● Define the term "AI" AI (Artificial Intelligence) is a machine's ability to perform cognitive functions like humans, such as perceiving, learning, reasoning, and problem solving (Johnson, 2022). ● Why is Artificial Intelligence important? AI can perform some tasks better than humans. For example, when analysing large numbers of legal documents to ensure relevant fields are correctly filled out, AI tools frequently complete jobs quickly and with few errors (Dingli, 2020). ● What is AI? Examples of AI in real life: Self-driving cars, Image recognition, Natural language processing, and Speech recognition.

computer vision, optical character recognition, and speech recognition. The history of facial recognition can be traced back to the 1960s. Early attempts were constrained by processing power, and some were only partially automated (Marqu'es, 2010). Nowadays, Face recognition technologies are used in different public areas, such as cafes, schools, shopping malls, and government buildings (Andrejevic & Selwyn, 2020). Face recognition is a technology that can identify or verify a subject based on an image, video, or other audio-visual element of the face. This identification is typically used to gain access to an application, system, or service (Electronic Identification, 2021). The learning objective of the third module is to learn how to detect faces in images and how facial recognition works. So, what is the impact of face recognition on society? The main points needed to discuss are, "Is facial recognition technology a safe method for securing sensitive information? and can facial recognition reliably be used to track individuals around an entire country?" (Benson, 2017). The related activity involves children playing with PictoBlox and sharing their ideas.

5.4.4. Module 4: AI ethics

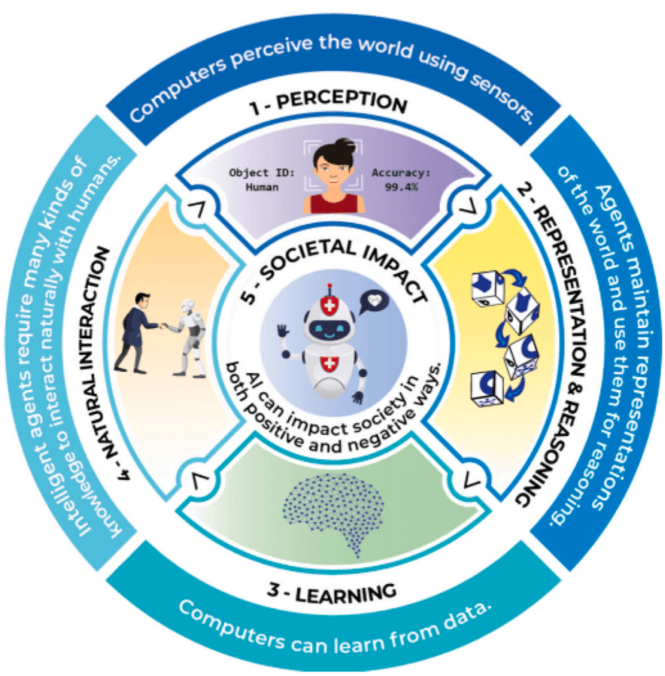
Children are introduced to the AI ethics in the fourth module (Table 7). The learning objective of the fourth module is to understand the flaws and biases of AI. Two biases can be seen in Artificial intelligence systems, such as data-driven bias and interaction bias (AI worldschool, n.d.). The fourth activity of the AI curriculum in ECE is children drawing AI helping humanity and sharing the ideas. The first activity in this module helps children gain a better understanding of AI. The second activity in this module helps children better understand all modules, for which they need to draw the concept map. Novak and his research group at Cornell University created concept maps in the early 1970s (Novak, 1998). Concept maps can help children to better understand concepts and their relationships, as well as externalize their ideas (Birbili, n.d.). There are several advantages of using concept maps, such as improving learning skills, understanding the course more easily, and improving memory. Concept mapping is extremely beneficial for children who struggle to learn and understand subjects in school (Mindomo, 2020). Therefore, the concept map is created as an evaluation of the child's mastery of this module.

5.4.5. Group project

We design smart plant (watering) projects for children (Table 8). This project can improve children's understanding on various aspects, such as understanding basis Micro: bit programming knowledge, reading the temperature and humidity values, using programming to control grow lights and water pumps, learning about the different parts of plants (i.e., flowers, leaves, stems, roots) and photosynthesis, and observing and recording plant growth factors. The learning objective is to understand programming knowledge. Each group has 3–5 children. This project aims to enhance children's critical thinking skills,

Table 4
Lesson plan for Module one (Part B).

Lesson 2: Introduction to AI (Part B)
Level 1 Grade: K3-5 (5–7 years old) Classroom time ● 30 mins introduction ● 10 mins assessment Learning objectives ● Understand the fundamentals of the Five Big Ideas Material needs Crayons A 4 × 6 card for each student Knowledge (30 mins) ● What is five big ideas in AI National guidelines for teaching AI in K-12 have been developed by the AI4K12 Initiative (AI4K12, 2020). The guidelines specify two things, first, what each child should understand about AI. Second, what children should be able to do with this guideline.

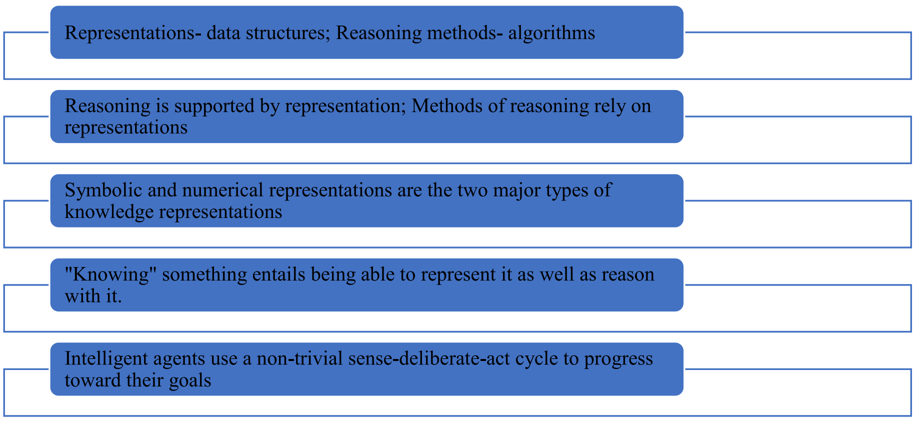


First Big idea- Perception
Perception is the use of knowledge to extract meaning from sensory information (AIK12, 2020).
Second Big idea- Representation & Reasoning
Computers keep world representations and use them for reasoning (AIK12, 2020). The following is a summary of second big idea (Representation & Reasoning).
Intelligent agents use a non-trivial sense-deliberate-act cycle to progress toward their goals
"Knowing" something entails being able to represent it as well as reason with it.
Symbolic and numerical representations are the two major types of knowledge representations
Reasoning is supported by representation; Methods of reasoning rely on representations
Representations- data structures; Reasoning methods- algorithms

(*continued on next page*)

Table 4 (*continued*)

Lesson 2: Introduction to AI (Part B)



Third Big idea- Learning
Data can help computers learn.

- Define the term “machine learning”
- How machine learning algorithms work
- What are machine learning algorithms and how do they work?
- The significance of training data
- The learning phase versus the application phase

Source: AIK12.org

Fourth Big idea- Natural Interaction
Natural interaction relates the ability to communicate intelligently and cooperatively, for example, similar to a human assistant who is aware of the user’s various characteristics, such as emotional state, tastes, and habits (Chu & Begole, 2010).

Fifth Big idea- Societal Impact
AI can have an impact on society in ways (i.e., positive and negative ways).

Assessment Suggestion
Each children need to draw a concept map

Activities (20 mins)
Children draw AI already used in our everyday life
Share the ideas
Summary

communication skills, and cooperation skills by using problem-based learning. Other group projects such as smart LED grow light, automatic humidity control, and smart environment (temperature control) are also suitable for children.

5.5. Teaching methods

We discovered that no research mentioned teaching methods while reviewing the relevant literature. We suggest project-based learning is more suitable for secondary and university education. Project-based learning (PBL) is mainly a learning-based curriculum model in which students actively discover and solve problems (Lou et al., 2017). Project-based learning (PBL) is a student-centered method of instruction based on three constructivist principles. Learning is context-specific, where learners participate actively in the learning process, and achieve their goals through social interactions and the sharing of knowledge and understanding (Cocco, 2006). Ferrero (2021) mentioned that project-based learning provides highly desirable benefits for students, such as the development of independent, self-regulated learners (Kokotsaki et al., 2016; Barak & Shachar, 2008; Donnelly & Fitzmaurice, 2005), the promotion of learning engagement (Harmer, 2014; Ravitz, 2009; Cornell & Clarke, 1999; Duke, 2016; Liu & Hsiao, 2002; Wurdinger et al., 2007), and the promotion of meaningful learning (Ravitz, 2009; Barron & Darling-Hammond, 2008). Several studies found that project-based learning methodology increased students’ learning motivation and achievement at the secondary and higher education level (Chiu, 2020; Williams, 2021; Holmes & Hwang, 2016). However, problem-based learning is more suitable for kindergarten children. Nowadays, problem-based learning is being used in a growing number of kindergarten classrooms (John et al., 2018; Dubosarsky et al., 2018). Numerous studies have discovered that problem-based learning can improve group cooperation and self-direction in young children (Pilliner, 2003; Lambros, 2002) and enhance 21st century learning skills (Tsoukalas, 2012). Moreover, children are naturally inquisitive from an early age, and they enjoy discovering new things and learning new things through hands-on activities (i.e., AI farming). For example, children will ask some questions, such as “How can we keep plants healthy?” and “What machine learning knowledge is applied in this AI farming activity?” in group project activities. These real questions can encourage children’s curiosity and desire for knowledge, promoting active learning. Throughout the project, teachers would not rush to provide answers; instead, they would guide the children in the direction of their questions and leave enough space for thinking. Children’s creativity, communication, teamwork, and other abilities will be improved after project learning. Also, we design group activities using problem-based learning, which usually require 3–5 people to finish the project. Every child has different strengths, and they must all work together to achieve their goals. In this process, students gain soft skills such as teamwork and reflection in addition to knowledge. Furthermore, children’s creativity, teamwork, and leadership, as well as hands-on skills, planning, and project execution, can all be exercised through group projects. Therefore, we suggest using problem-based learning in group activities.

We also suggest several teaching methods for teaching AI in ECE. Firstly, instead of emphasizing a specific AI concept or tool, children’s learning experience should be focused on achieving AI literacy through

Table 5
Lesson plan for Module two.

Module 2: Machine learning
Level 2 Grade: K3-5 (5–7 years old) Classroom time ● 25 mins introduction ● 5 mins summary Learning objectives ● Understand that machine learning concept ● Recognize that how machine learning works ● Know that machine learning examples Material needs iPad Knowledge (25 mins) ● Define the term "machine learning" Machine learning is a growing field of computational algorithms that aim to mimic human intelligence by learning from their surroundings (EI Naqa & Murphy, 2015). ● How machine learning works Machine learning is all about training an algorithm, and to train an algorithm, using a neural network, which is a collection of algorithms inspired by biological neural networks and modelled after the human brain and which is made up of individual neurons connected to one another (iD tech, 2020). ●Machine learning examples 1. Smart cars 2. Navigating the Complexities of web search 3. Automatic recommendation system Activity- Google's Quick Draw! (50 mins) Introduction: The website Quick, Draw! is a fun game for people of all ages where they can draw simple sketches of everyday objects and contribute them to neural network training (Anno.ai, n.d.). Ask for children play first Share ideas Question: How does the machine recognize drawings so well? The model is trained on a TON of data. The machine can predict brand new drawings after seeing enough examples of different styles of drawings and drawing patterns from them (ReadyAI, 2020).

Table 6
Lesson plan for Module three.

Module 3: Artificial Intelligence Techniques
Level 3 Grade: K3-5 (5–7 years old) Classroom time ● 25 mins introduction ● 5 mins summary Learning objectives ● Learn how to detect faces in images and how facial recognition works Material needs PictoBlox Knowledge (25 mins) ● Artificial intelligence techniques Face recognition: Face recognition is a technology that can identify or verify a subject based on an image, video, or other audio-visual element of face. This identification is typically used to gain access to an application, system, or service (Electronic Identification, 2021). ● How do we detect faces? Knowledge based method: The knowledge-based method relies on a set of rules and is based on human knowledge to detect faces (Towards Data Science, n.d.). Feature-based: Faces are located using the feature-based method by extracting structural features from the face (Towards Data Science, n.d). Video: https://www.readyai.org/quick-access/6-ai-applications/ Discussion: What is the impact of face recognition on society Group activity- PictoBlox (5–8 students each group) Example: Create Your Own Face Filters 1. Making the face filter library 2. Customizing the face filter sprite 3. Making the face filters clickable 4. Completing the script 5. Making the face filter Tilt 6. Conclusion

Source: STEMpedia

Table 7
Lesson plan for Module four.

Module 4: AI Ethics
Level 4 Grade: K3-5 (5–7 years old) Classroom time ● 25 mins introduction ● 5 mins summary Learning objectives ● Understand the flaws and biases of AI Material needs Crayons A 4 × 6 card for each student Knowledge (25 mins) ● How to develop responsible AI Video: https://www.media.mit.edu/articles/teaching-kids-the-ethics-of-artificial-intelligence/ Summary All modules Activity 1- Draw AI helping humanity Activity 2- Draw concept map (all modules)

Table 8
Group project.

Project Smart Plant (watering)
Grade: K3-5 (5–7 years old; 3–5 children each group) Activity time: 60 mins Learning objectives Understand the programming knowledge Material needs Soil Moisture Sensor Water Pump Multiple sensors of plant Multiple actuators for plant Connecting Wire Micro:bit USB Cable A glass of water Steps: ● Connect Multiple Sensors and Multiple Actuators by connecting wire ● Connect Water Pump and Pipe ● Connect Water Pump & Pipe to Water pump (D6/P1) port of Multiple Actuators ● Download the code and transfer to micro:bit ● Plug the micro:bit into Multiple Sensors

project-based learning and problem-solving (Kim et al., 2021). Secondly, the learning activities should be aimed at learning artificial intelligence (AI) knowledge and participating in AI activities in a fun and efficient way. Therefore, we draw concept maps, use AI to promote humanity, and link AI to our everyday activities to teach children. Moreover, concept mapping has been shown to be effective as a learning strategy for young children from kindergarten through grade five (e.g. Stice & Alvarez, 1987; Stow, 1997). Thirdly, teaching methods that include selecting appropriate e-learning tools and platforms in addition to traditional teaching methods can increase children's interest in learning. For example, Li and Chu (2021) investigate whether e-learning platforms (Reading Battle) can have a positive impact on children's academic performance. Result shows that children's active participation in the gamified e-learning platform can boost their reading motivation and abilities.

5.6. Assessment suggestions

When implementing our curriculum, we recommend several suggestions for children assessment. To begin with, it is unclear whether the children have previously been exposed to AI courses. Therefore, we can assess children's prior AI knowledge. A number of researchers have proven that it is valid and effective using assessment to assess children's knowledge (Williams et al., 2019a, 2019b). This can be done through comparison within two groups to see the differences. For the group that had never learned AI courses, we can pre-test and post-test AI knowledge to see how much their AI knowledge improvement after the courses. Meanwhile, it is also necessary to investigate differences in children's AI performance based on the their experience, age, grade, and gender. Second, we can observe classrooms and activities using the assessment profile. The Assessment Profile for Early Childhood Programs is an observation measure used in some studies to assess program quality (Abbott- Shim et al., 2000). The assessment profile is an observation checklist includes five scales, such as "Learning Environment (provisions for materials, child independence), Scheduling (balance and variety of activities), Curriculum (alternative techniques used to facilitate learning, children encouraged to be active in guiding own learning, curriculum individualized), Interacting (teachers' positive interactions, responsiveness, and management of children), and Individualizing (support for individualized learning experiences through assessment, parent communication, and referrals)" (Stipek & Byler, 2004, p. 378). Third, we can conduct teacher interviews to seek further suggestions for the improvement of the course. Finally, we can conduct a self-assessment questionnaire to ask children how much knowledge they understand compared to previous AI courses. Several studies have shown that self-assessment can improve student learning (Harris & Brown, 2013, 2018; Dearnley & Meddings, 2007).

6. Discussion

6.1. The significance of the study

The aim of this study is to provide an AI curriculum to educators and researchers. Many articles focus on AI tools or platforms (Lin et al., 2020; Nan, 2020; Vartiainen et al., 2020; Williams, 2019a), but the learning activities and curriculum design have received very little attention (Su & Yang, 2022). The learning outcomes of the children will increase their AI knowledge and skills. For example, children will enhance thinking. creativity, communication, and teamwork skills after group activities. Also, this study develops an AI curriculum framework for early childhood education, including aims or objectives, contents and activities, method or procedures, and evaluation and assessment. This curriculum framework can aid in the enhancement of teaching quality. Furthermore, this study outlines an AI curriculum for early childhood education, including AI knowledge, AI skills, AI attitudes (Table 1). First, AI knowledge includes basic AI concepts, five big ideas in AI, machine learning, application, and AI ethics. Second, AI skills include using AI tools, CT and programming, critical thinking, and problem solving. Third, AI attitudes include social impact and collaboration with AI.

In terms of teaching methods, we suggest that problem-based learning is more appropirate for kindergarten classrooms. AI in kindergarten and AI in secondary and university education are very different. AI in kindergarten mainly focuses on basic concepts and simple AI activities. However, AI in secondary and higher education mainly focuses on programming. Moreover, children are naturally interested in asking questions from an early age. We think that problem-based learning is more suitable for kindergarten children than project-based learning, especially in group activities.

In terms of assessment methods, we proposed several suggestions for children assessment, for example, using assessment (i.e., pre- and post-tests) to assess children's AI knowledge. This evaluation knowledge can clearly show whether or not the course is effective. Some studies assess children's AI knowledge using pre-and post-tests (Williams et al., 2019a, 2019b).

Lastly, this paper highlights the early AI curriculum, which can be used by educators and researchers as a resource. The paper provides designs of the various AI courses (concepts, teaching methods), teaching activities, and group projects, as well as lesson plans for each module, activities, and group project. These contents can help AI educators or researchers to find and develop the most appropriate courses for K3-5 students. These are based on the authors' personal experiences participating in relevant AI teaching and educational research. The paper also provides some assessment suggestions and future directions, which can help researchers design the early AI research.

6.2. Future directions

Early AI curriculum is a very new topic. Most studies relating to this topic were focused on secondary and higher education (e.g., Sabuncuoglu, 2020; Payne, 2019; Van Brummelen et al., 2021). Early AI education is a potential area. We suggest several future directions for researchers and educators as reference. First, we suggest that researchers or educators select appropriate e-learning tools or platforms as teaching material. For example, e-learning platforms (Reading Battle) can have a positive impact on children's academic performance and learning habits and interest (e.g., Li & Chu, 2021; Li et al., 2018; Mak et al., 2019). Second, early AI course is an independent subject. However, teaching AI courses to secondary and university students in the computer science subject (Kandlhofer et al., 2016; de Freitas & Weingart, 2021) requires formal teacher training. Therefore, early AI teacher education is also an important topic to research. It is worthwhile to research how to conduct teaching training for kindergarten teachers because all teaching requires training, particularly AI in the early stages of education. Third, it is also worth studying whether AI courses can improve children's 21st century skills. "The 21st century skills includes creativity, critical thinking and problem solving, collaborative skills, information technology skills, and new forms of literacy, and social, cultural, and metacognitive awareness" (Griffin & Care, 2014, p. 5). Most researchers conducted research on 21st skills in early childhood settings (e.g., Parette et al., 2010; Munastiwi, 2021; Main et al., 2021). Lastly, it is also worth investigating whether SES (Socioeconomic status) influences young children's AI learning. Some researchers found that SES will influence student achievement (Saifi & Mehmood, 2011). Furthermore, Druga et al. (2019) investigate whether SES will affect children's understanding of AI concepts. Result shows that high SES children understand AI concepts better than low SES children. Since there is only one study on this topic, which is insufficient to prove this result; however, it also implied that it is a very important and meaningful research area. We recommend that more researchers will investigate this topic in future.

7. Conclusion

This paper designs various AI courses (concepts, teaching methods), teaching activities, project, assessment suggestions, and provides future directions for researchers and educators. The research aims to develop an AI curriculum framework for early childhood education, as well as develop activities that can demonstrate the AI curriculum framework for early childhood education. The curriculum design includes three parts, AI knowledge, AI skills, and AI attitudes. This paper provides four modules, five activities, and one project for children, which will help AI educators and researchers to find and develop the most appropriate courses for K3-5 students, as well as help researchers design the early AI research. The teaching method of problem-based learning is suitable for early AI teaching.

We identified four assessment suggestions. First, assess children's AI knowledge by using pre-test and post-test. Second, conduct observations on classroom activities using the assessment profile (Assessment Profile for Early Childhood Programs). Third, conduct teacher interviews to improve the AI curriculum design. Fourth, conduct a self-assessment questionnaire to assess children's knowledge by themselves. Lastly, we recommended some future directions for researchers. First, we suggest selecting appropriate e-learning tools or platforms as teaching material.

Second, more research need to be focused on early AI teacher education. Third, it is also worth studying whether an AI curriculum can improve children's 21st century skills. This paper has two main contributions. First, since studies on AI curriculum in early childhood is far from sufficient in the existing literature, this paper aims to design AI curriculum, AI activities, and AI project for K3-5 children (5–7 years old), which will help educators design the suitable AI course for children and help researchers design the AI curriculum for research. Second, this study proposed a new guideline of early AI curriculum for future researchers as a reference.

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.

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