Chapter 5 - Design of Artificial Intelligence (AI) Education for Primary Schools: Arts-based Approach

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Chapter Highlights

- The study aims to design an AI curriculum framework with a pedagogical strategy and assessment method to support students in developing their AI literacy in a primary school setting.
- Theoretically, by adding the new element of AI thinking with the considerations of data justice and ethics into the existing theoretical AI literacy framework, this research presents a holistic and inclusive AI curriculum for primary school students, with the considerations of all humans, non-humans, and nature.
- This curriculum can demystify AI concept skills traditionally taught at secondary schools and universities. The educational implication is that it may empower students with the agency for critically creating and evaluating AI models while considering minimizing any potential bias and its societal, ethical, and environmental implications.
- Apart from shedding light on the suitability of AI curriculum in primary school settings, this study contributes to our understanding of the effectiveness of pedagogical strategy in AI curriculum implementation. It also adds value to assessment groundwork to evaluate AI literacy.

Introduction

Artificial Intelligence (AI) is defined as "the science and engineering of creating intelligent devices, particularly intelligent computer programs" (McCarthy, 2007, p. 2). AI literacy has become an essential component of national strategies for digital citizenship education (Seldon & Abidoye, 2018). Even though many youngsters have grown up engaging with AI algorithms, the majority of them still do not understand the technologies underlying smart toys and AI applications (McStay & Rosner, 2021; Ottenbreit-Leftwich et al., 2021), while some even hold misconceptions and misinformation about AI (Mertala et al., 2022; Dai et al., 2023). Many academics believe that younger children should be taught how to interact with and use AI-powered applications since AI education nurtures creativity, enhances problem-solving skills, and develops persistence, allowing students to meet the needs of the 21st century (Touretzky et al., 2021; Taguma et al., 2018). The urgency for AI literacy education is further heightened by the prevalent dark side of AI, including the algorithm bias reinforcing the existing social, economic, and political bias in AI training datasets (Benjamin, 2019; Crawford, 2021). They will significantly impact humans and natural ecosystems in the 21st century (Bozhurt et al., 2021; Crutzen, 2002). AI also threatens children's rights to privacy, safety, and security (Maio et al., 2022), so recent discussions have focused on how important it is to learn AI ethics (Gong et al., 2020; Hagendorff, 2020), data justice (Atenas et al., 2023; Raffaghelli & Gouseti, 2021), and how to teach children to think critically in an age of intelligence (Floridi et al., 2018). Furthermore, there have been calls for including primary school students in AI literacy education to maximize digital inclusion and eliminate the digital divide (Yang, 2022). Given the extent to which AI technologies have infiltrated various aspects of our lives, AI education should be promoted in primary school settings with the consideration of all humans, non-humans, and the natural world rather than being limited to secondary school or university settings (Chiu et al., 2021b; Su et al., 2022).

Given the urgent need to teach primary school students about AI literacy, this study aims to design a holistic AI curriculum, including AI thinking with data justice and ethics, with the collaborative arts-based pedagogical strategy and assessment method. It strives to empower young students with AI literacy to be a social, ethical, and environmentally responsible AI generation to advance a more equitable, just, and sustainable world. It provides an engaging and content-appropriate AI curriculum for primary school students. The contribution of this study is fourfold: (1) the holistic arts-based AI curriculum for inclusive primary education proposed in this study serves as a valuable reference for educators and the government; (2) it sheds light on the suitability of AI primary education curriculum and contributes to the understanding of the effectiveness of the pedagogical strategy in the implementation of AI curriculum; (3) it designs and provides suitable content, teaching methods with engaging and age-appropriate AI learning tools, teaching activities, assessment suggestions in the AI primary education field to inform teachers and practitioners for iterative and sustainable AI literacy educational development; (4) it empowers students with AI literacy with a collaborative arts-based pedagogical approach and inspires them to be a AI creator who creates for projects using AI technology.

Research Aims and Questions

The study aims to design an AI curriculum framework with a pedagogical strategy and assessment method to

empower students in developing their AI literacy in a primary school setting. The following research questions will guide the proposed study.

- RQ1: What learning content should be included in AI education at the primary school level?
- RQ2: What are the teaching methods in group activities?
- RQ3: What are the assessment suggestions in AI education at the primary school level?

Literature Review

AI Literacy and Conceptual Framework

AI literacy has become essential in the 21st century, including fundamental grammar and survival competence across several fields (Miao et al., 2022; Touretzky et al., 2022). It has grown to include a range of ideas, knowledge, abilities, and attitudes (Long & Magerto, 2020). Some academics describe it as knowing and comprehending AI, using and applying AI, assessing and constructing AI, and AI ethics (Ng et al., 2021), which are as vital as reading, writing, and computer skills. Machine learning, algorithm design, and natural language processing are also considered AI subfields of computer science (Akgun & Greenhow, 2021). More crucially, primary school research must be addressed in favor of secondary schools (Chiu et al., 2021b) and universities (Su et al., 2022).

Recently, the Machine Learning Education Framework (Lao, 2020), Digital Competence Framework For Citizens (Guitert et al., 202a), and AI4K12 initiative (i.e., a scientific-related industry partnership https://ai4k12.org/) of Five Big Ideas in AI (Touretzky et al.,2019) have been adopted to design an AI curriculum for students. For example, researchers introduced the Five Big Ideas in AI, which comprises perception, reasoning, representation, machine learning, and language understanding, to K-12 students (Tkáčová et al., 2020; Eguchi et al., 2021; Touretzky et al.,2021). These guidelines are informed by the learning sciences and computer science education research and aligned with the CSTA's K-12 Computer Science Standards, Common Core, and Next Generation Science Standards (Touretzky et al.,2022). Therefore, the learning of AI literacy education is often incorporated into the computer science curriculum (Kanemune et al., 2017) and mapped into the Science curriculum (Heinze et al., 2010). Due to gender differences (Dai et al., 2020), situated AI literacy education may bar certain groups of students (Lin et al., 2021), particularly girls, from engaging in learning.

In addition, many argue that data is the core of the contemporary approach to AI development, which contributes to the numerous challenges centered on ethics, justice, and algorithmic bias (Benjamin, 2019), as well as accountability and transparency for inclusive and sustainable development (Pedro et al., 2019). AI has the potential to amplify hidden biases and prejudices in its initial data analyzed and trained by humans, potentially reinforcing its underlying assumption (Crawford, 2021). For example, the design of AI personal assistants such as Alexa and Siri is inherently anthropomorphic (Pfeuffer et al., 2019), and they were given female names, perpetuating discriminatory stereotypes of female secretaries and male bosses. Adam (2006) even argues that AI

is a model of gender that reinforces women's subordination to men (Nadeem et al., 2022). This is a fundamental question that AI literacy education should address to advance what it represents to be fully human. Given that the learning content of AI thinking about data justice and ethics is often undermined in the framework and curriculum design for young students (Touretzky et al.,2019), teaching them about the critical role of data in AI training datasets is paramount (Mertala et al., 2022).

AI Literacy Primary Education

One of the biggest challenges is scaffolding AI concepts to primary school students engagingly (Yang, 2022). There have often been unresolved debates over how young students' engagement can be maximized when learning about AI concepts (Sakulkueakulsuk et al., 2018) and what pedagogical strategies and learning tools are appropriate (Steinbauer et al., 2021). Previous empirical research has indicated that AI learning content can be taught through project-based (Narahara & Kobayashi, 2018; Ho et al., 2019), game-based (Voulgari et al., 2021) and collaborative learning (Toivonen et al., 2020; Vartiainen et al, 20.20) with the use of constructivist methodologies in primary school classrooms (Ho et al., 2019; Lee et al., 2020). These approaches align with UNESCO reports that current AI literacy education reflects the dominant belief of constructivism and constructivist ideologies (Miao et al., 2021). Although they are considered effective in encouraging students to learn by doing according to their interests (Miao et al., 2022), they proposed that knowledge can only exist within the human mind (Bada & Olusegun, 2015), which suggests the exclusion of other ways of knowing (Colucci-Gray et al., 2019) and that it is not connected to the relationality of the embodied interaction (Dai et al., 2023), the materials and natural world (Braidotti, 2019). In addition, this variation in pedagogy could also be influenced by various factors in the teaching and learning process, such as students' age, gender, background knowledge, educational settings, and available learning tools.

Previous studies have also demonstrated that incorporating the arts into various disciplines, such as STEM (acronyms of Science, Technology, Engineering, and Mathematics), can enhance girls' interest (Martínez et al., 2021; Ma et al., 2022), promote students' participation at all ages (Papavlasopoulou et al., 2019) and help them learn new knowledge and skills (Ballard et al., 2023; Kuri, 2020). Although the educational purpose of the arts is to unlock students' multiple perspectives by reviewing their roles in ongoing interactions and relationships with other humans, non-humans, and the natural world (Colucci-Gray et al., 2019), an arts-based approach in AI literacy learning is absent.

In the age of Generative AI, human and AI interaction is evident in almost all aspects of everyday life. Though many children are digital natives who grow up while interacting with AI algorithms, most of them are still AI illiterates. Children frequently treat AI models as black boxes, failing to understand computational thinking concepts, underlying assumptions, or AI model constraints (Shamir & Levin, 2021; Burgsteiner et al., 2016). However, there are increasingly more learning tools available, including hardware-focused learning tools such as robots (Narahara & Kobayashi, 2018) and Raspberry Pi (Mathe et al., 2022); software-focused learning tools such as Scratch (Li & Song,2019), intelligent agents such as Google Teachable Machine, Learning ML (Toivonen et al., 2020; Rodríguez-Garciá et al., 2020); and unplugged activities such as role play (Henry et al., 2021). Even

though algorithm bias can be visualized and taught at the primary school level (Narahara & Kobayashi, 2018; Melsion et al., 2021), the majority of these tools are employed to scaffold the basic AI concepts and knowledge to teach students about future AI consumers and users rather than critically understand the role of data for future AI designers and creators (Ng et al., 2021). Given that early exposure to AI literacy can prepare students to adapt to future needs (Burgsteiner et al., 2016), AI literacy education should be prioritized to build a future generation that is digitally, globally, and socially responsible. Nonetheless, AI remains contested due to the scarcity of research on what to learn, how to teach, and the effectiveness of pedagogical strategies and tools in teaching young students in primary school settings (Steinbauer et al., 2021; Yang, 2022).

AI Curriculums and Activities Design Under Current Primary Educational Settings

Recently, many researchers have been designing, experimenting with, and advocating for an AI curriculum to be included in the primary school curriculum. Many have worked with governments such as the Ministry of Education of the People's Republic of China (Dai et al., 2020), the Victorian Curriculum and Assessment Authority of Australia (Heinze et al., 2010), the city-wide educational program in Israel (Shamir & Levin, 2021), and the "Digital Technologies in Society curricula" of Slovakia (Tkáčová et al., 2020). Others have worked closely with non-governmental organizations, such as the AI4ALL initiative (Touretzky et al., 2019; Eguchi et al., 2021) and the MIT Media Lab (Ali et al., 2019). Constructionism (Ali et al., 2019; Shamir & Levin, 2022) and the AI4K12 Five Big Ideas Framework (Tkáčová et al., 2020; Eguchi et al., 2021) have been applied to design AI curricula in current primary school contexts. Although previous researchers have identified the types of content knowledge and theoretical frameworks to be included in school-based curricula for primary students, most studies use subjective measures such as artifact assessments (Ali et al., 2019; Li & Song, 2019; Shamir & Levin, 2021), self-reported surveys, and interviews (Chai et al., 2021a; Dai et al., 2020; Melsion et al., 2021) to understand their learning outcomes. These measures reflect the inadequacy of measurable applications or evaluations of knowledge mechanisms in assessing the quality of suggested methodologies for primary school students. According to UNESCO 2022, evidence based on AI curriculum quality, suitability, and effectiveness is needed (Miao et al., 2022). As a result, there is a need to expand on the existing work on AI in primary school contexts.

Research Gaps

The literature review reveals several gaps. First, AI education is primarily implemented at universities and secondary schools. Despite the availability of more age-appropriate learning tools for young students, there are insufficient efforts to promote the element of AI thinking with data justice and ethics. Second, many researchers advocate for developing and implementing AI curriculum and activities to educate students about AI knowledge, skills, and AI ethics issues from an early age; however, AI curriculum for primary school students is typically limited. There is an urgent need to design age and content-appropriate curricula to enrich the existing literature. While previous research has proposed various approaches to AI education, this study expands on the existing studies using the arts-based approach. Moreover, since ethics and AI technology are inextricably linked, research on incorporating AI thinking with the consideration of data justice and ethics into the AI curriculum is required. Assessment suggestions on assessing students' and teachers' perceptions of AI literacy education, investigating

the suitability of the curriculum, and evaluating AI literacy, typically lacking in previous studies, are also developed in this study for improving learning outcomes.

The Researcher's AI Curriculum Design

This section will describe the AI curriculum design administered by the researcher for the objective of this study. It aims to explore a dynamic interaction of material and discursive learning settings – the entanglement of arts-based AI learning contents, arts-based materials, and AI educational tools. Considering all humans and non-humans and the nature of sustainable and inclusive AI literacy education, six learning modules are designed by the researcher to empower students with AI knowledge, skills, and a critical mindset, together with AI attitudes about AI thinking about data justice and ethics.

AI Curriculum Design for Primary Education

Based on the frameworks of the Five Big Ideas (Touretzky et al., 2019), an AI arts-based curriculum is designed by adding the Sixth Big idea, AI thinking with data justice and ethics (Figure 1). It encourages students to consider all humans and the nature of their study, reflect on the credibility of AI-based training and analytical techniques in data justice and ethics, and understand how the AI dataset should be created and used critically to avoid bias. AI thinking was first introduced by Zeng (2013) to harness cognitive computational data analytics, leading to enhanced learning by interpreting new findings from the machine learning exploration of hidden data patterns (How et al., 2020). It values the interwoven existence of human and non-human nature and its actions, promoting a more equitable and sustainable AI literacy education for all.

Big idea 1: Perception - By using sensors, computers can perceive the world
Big idea 2: Representation and reasoning - AI agents have representations of the world for reasoning purposes
Big idea 3: Learning - Computers can learn from data
Big idea 4: Natural interaction - AI agents require various types of knowledge to interact with humans naturally
Big idea 5: Societal, ethical, and environmental impact - AI poses both positive and negative impacts.
Big idea 6: AI thinking with data justice and ethics - AI dataset should be created and used critically to avoid bias

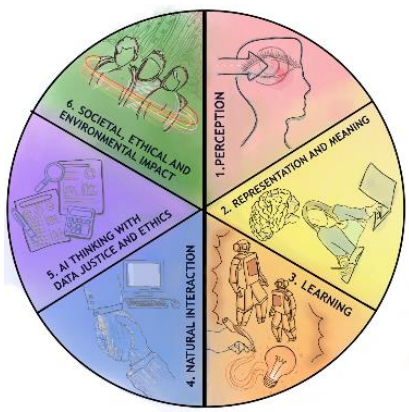

Figure 1. The Big Six Ideas designed by the researcher (adapted and modified from Touretzky et al., 2019)

As illustrated in the UNESCO report, AI literacy is an orientation of three main learning goals in AI curriculum, namely 1) AI foundations (i.e., Knowledge), 2) Understanding, using, and developing AI (i.e., Skills), and Ethics and social impact of AI (i.e., Attitudes and values to all humans, non-human and nature as proposed in this study) (Miao et al., 2021 & 2022). The AI curriculum framework design for primary education of this study (adapted from Su & Zhong, 2022) is then mapped to these three learning goals (Table 1).

Table 1. The AI curriculum framework (adopted from Su and Zhong, 2022)

AI Knowledge	AI Skills	AI Attitudes
K1: Definition of AI & examples of AI	S1: Using AI tools	A1: Societal impact A2: Global and Environmental Impact A3: Dialogic and collaborative with AI and humans
K2: The SIX Big Ideas in AI	S2: Computational Thinking	
K3: Machine Learning	S3: Communication and Collaboration	
K4: AI Applications	S4: Critical Thinking and Problem-Solving	
K5: AI Ethics and Data Justice	S5: Creativity	
	S6: AI Thinking with data justice and ethics	

The structure of the AI primary curriculum consists of six modules, which lasted for twelve weeks (Table 2). The six modules are 1) Basic AI, 2) Machine Learning, 3) Teachable Machine, 4) AI Applications and Implications 5) Group Arts-Project, and 6) Group Presentation and Dialogic Learning. Each module is designed with two 1.5-hour sessions. Each session has specific learning goals, learning tools, activities, and suggested assessment methods (Table 3).

Table 2. The structure of the arts-based AI primary curriculum

Modules	Knowledge	Skills	Attitudes/ Value	Level of Difficulty	Sample Learning Activity
Module 1: Basic AI	K1, K2	S5, S6	A1, A2, A3	1	Turing test, "Imagine AI and arts-making" activity "Quick and Draw" activity *https://quickdraw.withgoogle.com*;
Module 2: Machine Learning	K1, K3, K4, K5	S1, S2, S5, S6	A1, A2, A3	2	"Confusing the AI" activity, "Biasing the AI" activity MachineLearningforkids, RaspberryPi *https://machinelearningforkids.co.uk/* *https://www.raspberrypi.com/*
Module 3:	K1, K3, K4, K5	S1, S2,	A1, A2,	2	"Dance with the codes" activity

Teachable machine		S5, S6	A3		Google teachable machine *https://teachablemachine.withgoogle.com/*
Module 4: AI applications and implications	K1, K3, K4, K5	S1, S2, S5, S6	A1, A2, A3	2	"Draw Bot" activity Video, digital books and related learning material (e.g Better off Ted "Racial sensitivity", "Fake Obama") *https://www.youtube.com/watch?v=XyXNmiTIupg* https://www.youtube.com/watch?v=AmUC4m6w1wo Youtube redesign *https://www.media.mit.edu/*
Module 5: Group Arts-based Project	K1, K2, K3, K4, K5	S1, S2, S3, S4, S5, S6	A1, A2, A3	3	AI computer vision car, AI arts generation, computer visions and virtual space applications
Module 6: Group Presentation and Dialogic Learning	K1, K2, K3, K4, K5	S1, S2, S3, S4, S5, S6	A1, A2	3	AI computer vision car

Table 3. Six modules of AI primary curriculum

Module	**Lesson Goals**	**Pedagogical strategies**	**Assessment suggestions**
Module 1: Basic AI	Understand the what AI is, the history of AI, why now, any misconceptions, and Six Big Ideas	Arts-based	Knowledge test, survey, interview Artifacts- and arts-process assessment
Module 2: Machine Learning	Understand what is ML, how machines learn, the critical role of data (justice and ethics)	Arts-based, project-based	Artifacts, and arts-process -assessment
Module 3: Teachable machine	Apply with understanding of who can use ML, how ML is used, Why ML is used, and the importance of AI thinking in relation to data justice and ethics	Arts-based, project-based	Artifacts, and arts-process -assessment
Module 4: AI applications and implications	Understand, Create, and Evaluate the technologies underlying AI applications as well as their humanistic, societal, global environmental, ethical, and data justice implications	Arts-based, project-based	Knowledge tests, surveys, interviews
Module 5: Group Arts-based project	Applying knowledge, skills, and attitudes in group projects and solving a real-world challenge with	Arts-based, project-based	Artifacts, and arts-process -assessment

	the consideration of humans, non-human and nature orientation	
Module 6: Group Presentation and Dialogic Learning	Collaborate with humans and computers, be a problem solver	Project-based

Module One- Basic AI

The basic AI concepts will be introduced to primary students in the first module. Through the exploration of dynamic interactions of material discursive learning settings, the objective is to build a conceptual understanding of what AI is, understand the misconceptions, the history of AI, and the reasons for learning about AI literacy. The researcher designs the activities to allow the entanglement of arts-based AI learning contents, materials, and AI educational tools. For example, to recognize that learning can be a collective process of knowing, doing, and being (Barad, 2007), the activity of "Imagine AI and arts-making" is designed (Figure 2). It allows understanding of students' perceptions of AI (Mertala et al., 2022). The tools and platforms such as "Quick and Draw" (https://quickdraw.withgoogle.com/) are introduced (Tkáčová et al., 2020), which adopts a neural network artificial intelligence to guess what the drawings represent. Pietikäinen and Silven (2022) argue that the history of AI and the Turing Test is important as they can clearly explain what AI is and demonstrate the machine's intelligent behavior, equivalent to humans' (Figure 3). As such, educational tools such as ChatGPT will be used in the "Turing Test" activity for dialogic learning to enhance students' understanding of AI, data justice, and ethics issues.

Figure 2. The "Imagine AI and arts-making" activity designed by the researcher

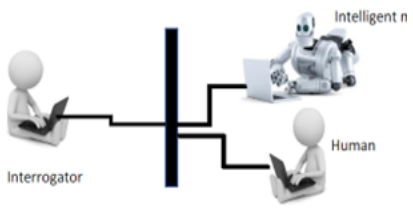

Figure 3: Turing Test (Pietikäinen and Silven 2022)

Module Two: Machine Learning

The learning objective of the second module is to understand what machine learning is, how machines learn with demonstrations and examples, and to evaluate or create a machine learning model to minimize any potential bias in the training datasets. Machine learning focuses on the use of data and algorithms to mimic how humans learn and improve automatically through experience, which is considered as a vital part of future computational skills (Jordan & Mitchell, 2015). Instead of relying on the explicitly hand-coded (e.g.if-then rules), many machine learning initiatives focus on using open-ended tools to guide primary students to train machine learning models by scaffolding the machine learning concept (Voulgari et al., 2021). "Machine Learning for Kids" allows students to understand basic block programming and explore the machine learning classification (Lane, 2021), while the use of Raspberry Pi helps to explore the machine learning data and its application (Norris, 2020). As machine learning is a subset of AI, a type of data-driven thinking, it aids the development of decision-making models based on various mathematical data sets, such as computer vision, face, voice, and text recognition (Webb et al., 2021). The "Confusing The AI" and "Biasing The AI" projects (Lane, 2021) will allow students to understand the unintentional and intentional bias involved in the data training that humans provide. The artifacts of their training models can be used as data collection for AI assessment.

Module Three: Teachable Machines

In the third module, the Google teachable machine will be introduced to students for creating and applying machine learning models. The learning objective is to allow students to understand who can use machine learning, how and why machine learning is used, and how AI thinking considers data justice and ethics. Google Teachable Machine is a viable and appropriate tool for students with little or no prior programming or related experience to learn AI (Prasad et al., 2022). Toivonen et al. (2020) reveal that using Google teachable machines to teach convolutional neural networks to classify images, voice, and text for understanding ML concepts in a primary school context is technologically and pedagogically feasible and effective. It is a web-based solution that combines powerful classification algorithms with an easy-to-use graphical user interface. It allows students to apply their knowledge, be actively involved in the machine learning training process, and become a designer and creators of their education (Prasad et al., 2022). This module will then adapt Carney et al. (2020) to use Google teachable machines for students to create, use their classification models, and explore enhancing the model's accuracy (Figure 4). The assessment can be drawn from the prediction accuracy of Google Teachable Machine based on the work of students (Figure 5).

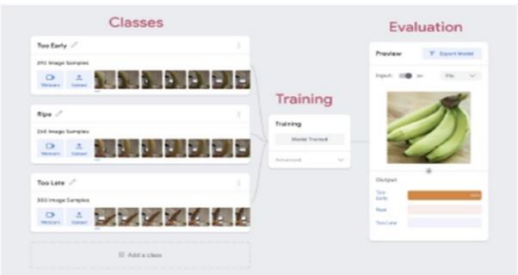

Figure 4. Teachable Machine Interface (Carney et al., 2020)

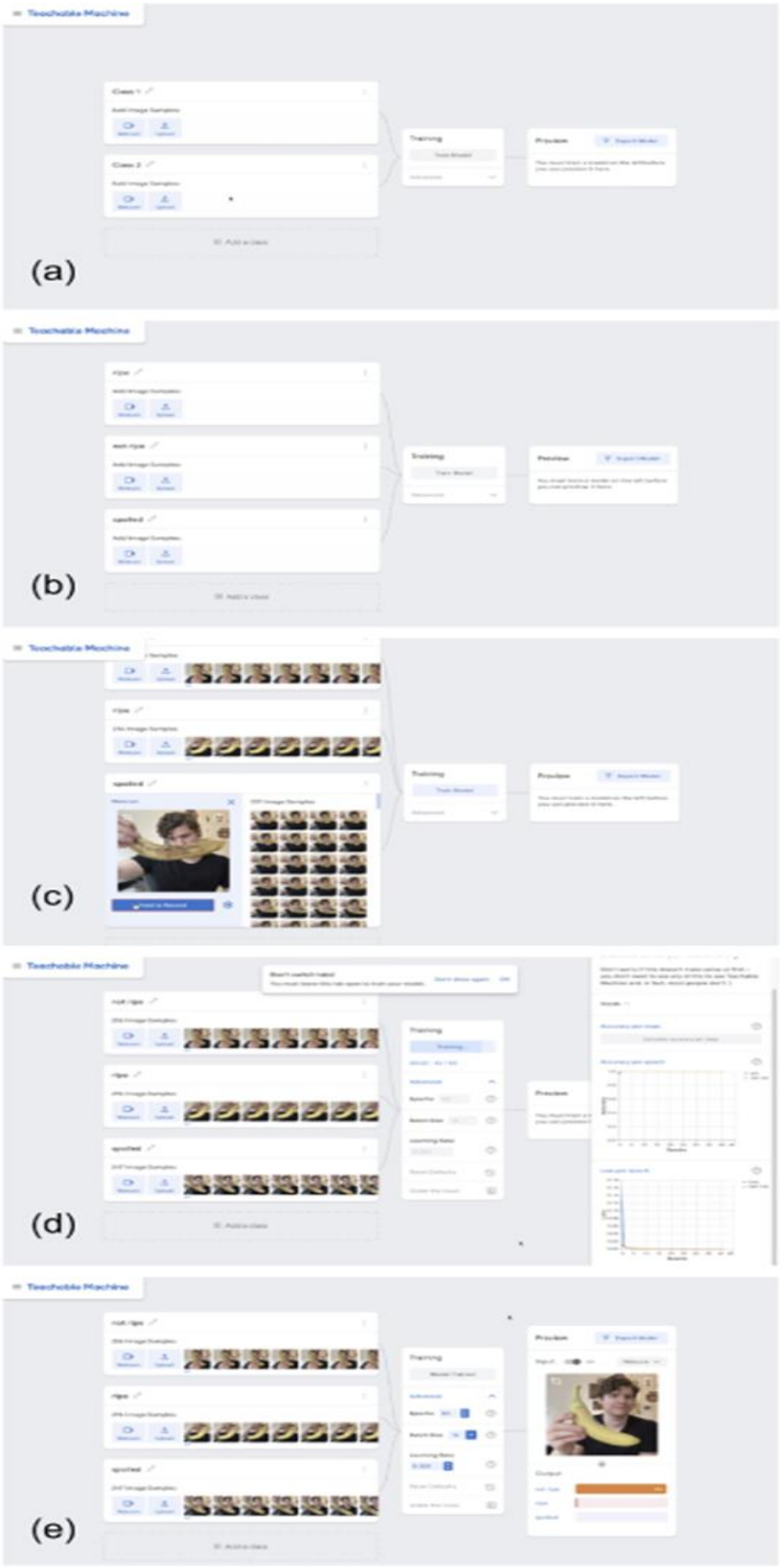

Figure 5. Teachable Machine Training Steps (Carney et al., 2020)

Module Four: AI applications and implications

AI has been applied in almost every aspect of life such as medical care, education, transportation and economy (Sestino & De Mauro, 2022). The learning objective of module four is to allow students to understand the technologies underlying AI applications as well as its humanistic, societal and ethical implications (Kaspersen et al., 2021). "Draw Bot" activity is designed to show students the AI light sensors embedded, which can be used for drawing line detention and the limitations of AI in relation to the data. Videos and digital books about the related AI applications learning resources will also be used in class. For example, the video of "Better off Ted Racial Sensitivity" illustrates the critical role of AI data justice and ethics by exploring the issue of AI aggravating existing social and racial discrimination in society. The video of "Fake Obama" that was created by the researcher of New York University which used AI tools to put any words into the synthetic Barack Obama's mouth (https://www.youtube.com/watch?v=AmUC4m6w1wo) will also be discussed. Students will engage in high-order thinking activities such as group discussions, opinion lessons and debates. "Youtube redesign" will be introduced to students to allow them to apply what they have learnt and construct an ethical matrix of Youtube recommendation algorithms. Through the identification of stakeholders and their values in algorithms, AI societal and ethical implications can be explained (Akgun & Greenhow, 2021).

Module Five: Group Arts-based Project

The learning objective of module five is to assemble and construct an AI intelligent vision car that allows students to apply their knowledge in a collaborative arts-based project to solve real-life challenges. Through the "Dance with codes" activity, students are introduced to the concept of AI algorithms and coding and designing steps for AI strategy to complete a task. An AI computer vision car will then be introduced in this module (Figure 6). It is a robotic vehicle kit based on a graphical, block, and Python program. It requires students to assemble and train the model with road signage, number, color, tag, and landmarks recognition data. The teaching task decomposition and teaching points of this project are shown in Table 4. Students will be asked to form a group and design an AI road map with safety measures with human and non-human orientations for an AI self-driving game to demonstrate their application of knowledge, skills, and attitudes. Through peer collaboration and dialogic human-computer interactions, it provides opportunities for students to engage in high-order thinking and examine the power and threats of AI.

Figure 6. The example of "AI Computer Vision Car"

Table 4. The teaching decomposition of "AI Computer Vision Car"

Project	Teaching task decomposition	Teaching Points
AI	assemble and construct a AI intelligent vision robot car	A hands-on project to stimulate students' interests to learn, collaborate with teams and be a problem solver as well as know how to communicate across different technology platforms.
Computer Vision Car	Block-based programming	use block-based programming that allow students to develop their computational thinking skills
	AI recognition such as Road Signage, Number, Color and tag/landmark recognition	Allow students to input data to train the model to recognize Road Signage, Number, Color, Tag and landmarks recognition
	AI vision tracking	Apply AI recognition, students design their AI traffic map for AI computer vision car game so as to enhance student ability of comprehensive application of knowledge as well as understand the AI thinking in relations to data justice and ethics
	AI ethics and data justice	Through learning from design. Dialogic learning with AI and all humans. Students should be able to understand the benefits and threats of this AI computer vision car to society

This curriculum design has incorporated projects with arts-based pedagogy in the learning process. This project is adopted from the seven-phase project-based learning model of Jalinus et al. (2017), which summarizes the core elements to enhance students' competencies through real learning experiences following problems and needs (Table 5).

Table 5. Seven-phase project-based learning (adopted from Jalinus et al., 2017)

Project-based learning	Seven Steps	Using AI Computer vision car as an example
Skills Competency debriefing	1. The formulation of expected outcome	By using a contextual teaching and learning approach and motivate students to make connection between the knowledge and the real world situation (e.g. the conceptual understanding of AI algorithms and codings are introduced through embodied interaction and dance)
	2. Understanding the teaching materials	Students actively involved in discussions about AI Computer vision car and its functions being studied as an instructional media (e.g.Al vision for color, label and number recognition)
	3. Skills training	Through demonstration and practice, students master the technical content and operational machinery skills before carry out the project tasks (e.g.graphical, block and Python programming)
Project work	4. Designing the project theme	Discuss, identify and define the real-world challenges as the theme of the project tasks through sources of information such as interviews and

		internet sites. (e.g. students design the AI roadmap with safety measures in relation to human and non-human orientation for AI computer vision cars).
	5.Making the project proposal	It consists of problems and solutions, availability, cost and suitability of resources for production.
	6.executing the tasks of project s	Practical activity required team works, carry out the learning process through inquiry investigation and constructing work on project tasks
Evaluation	7. Presentation of the project report	Students present own perception, evaluate one another critically, learn from feedback and reflection

Module Six: Group Presentation and Dialogic Learning

The last module aims to provide an opportunity for students to share their collaborative production experience by creating complex artifacts and presenting their solutions in physical and virtual collaboration spaces (Figure 7). Students will be asked to form a team to promote collaboration and communication. They must formulate the expected outcome, understand the teaching materials, practice skills, create AI arts, design the project, and execute it following their roles. Encouraging students to construct their artifacts for assessment, examine and question the trustworthiness of AI applications, and present their solutions in real-life context skills (Long & Magerko, 2020) and in virtual space can develop their critical thinking and problem-solving. Reflection on their dialogic learning process with AI and peers and presentation of their artifacts can demonstrate their AI literacy development while improving social interaction.

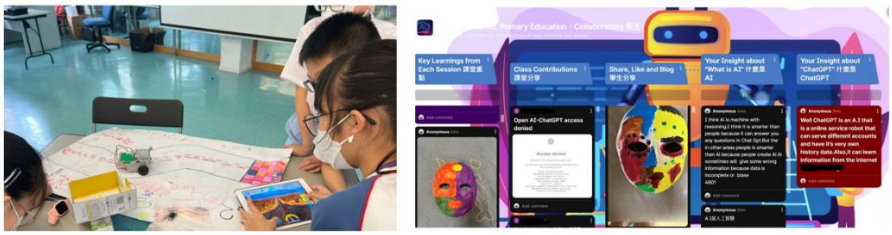

Figure 7: Collaborative arts-based projects presentation and dialogic learning

Suggestions on Assessment

As suggested by UNESCO (Miao et al., 2021 & 2022), the goals and learning outcomes of AI curricula should focus on the knowledge, values, and skills needed not only for schools but also for work and life in the AI era. Researchers face challenges in scaffolding young students to understand AI concepts due to technical complexity and the fact that most students do not have prior AI knowledge (Steinbauer et al., 2021). As AI learning assessments have not yet been rigorously validated (Su et al., 2022), this study suggests using a mixed method not for selection but for improving learning and teaching for sustainability.

First, pre and post-tests are designed by the researcher based on the arts-based AI curriculum to assess students's knowledge (Table 6), which can become an effective assessment method to understand their learning outcomes in AI knowledge and skills (Lin et al., 2020). Second, it is found that students need to have self-efficacy, AI readiness, AI for social goods, and behavioral intention to promote the development of their AI literacy (Ayanwale et al., 2022; Chat et al., 2021a). They acknowledge teachers' and students' perceived readiness to teach and learn AI, respectively, and their willingness to be engaged in AI literacy education in the long run (Chai et al., 2020a; Chai et al., 2021). Third, interviews with teachers are needed to support their voices for the readiness of AI literacy teaching (Clark, 2011), as teachers' efforts and classroom practices are indispensable in AI education (Roll & Wylie, 2016). Fourth, an artifacts creativity process assessment is recommended. This assessment is an observation based on the international OECD assessment rubric for evaluating the arts-making and learning process and the artifacts so that teachers can give feedback, understand students' performance, and propose better teaching strategies (Vincent-Lancrin et al., 2019). A diversity of assessment methods is suggested to bridge the learning gap following students' demonstrated needs. At the same time, these measurable applications can triangulate students' AI literacy learning outcomes (Kandlhofer et al., 2016).

Table 6. AI Knowledge Test designed by the researcher

Knowledge Test Questions	**Correct Answer**
1. All robots are Artificial Intelligence?	FALSE
2. Which of the following is (are) correct?	(I), (II) and (III)
(I) Artificial means "non-human"	-
(II) Artificial means "not just machine"	-
(III) Intelligence means "intellectual power such as strength, speed, specific knowledge a particular task required"	-
(IV) Intelligence means "omniscient, all knowing and perfect"	-
3. Which of the following is (are) the Big Six ideas of AI	(D)
A. Perception, representation and reasoning,	-
B. Learning, natural interaction,	-
C. AI thinking with data justice and ethics	-
D. All of the above (correct answer)	-
4. What does the "Imagine AI and arts making" project help you to understand?	(A)
A. The conceptual understand of what is AI literacy meant to me (correct answer)	-
B. The history of Artificial intelligence development	-
C. The limitations of AI	-
D. The AI technologies are ubiquitous in daily lives	-
5. What does the "Quick and Draw" AI applications help you to understand?	(I), (II) and (III)
(I). An online game developed by Google	-
(II). It challenges me to draw a picture of an object or	-
(III). It uses a neural network artificial intelligence to guess what my drawings represent	-
6. What does the "Draw Bot" AI educational tool help you to understand?	(I), (II) and (III)
(I). A robot that follows the black line I draw	-

(II). Light sensors help to trace Draw Bot detect and trace the black trail automatically	-
(III). I can learn while drawing	-
7. What does the "Dance with the codes" project help you to understand?	(I), (II) and (III)
(I). The conceptual understand of what is artificial intelligence algorithm (correct answer)	-
(II). The steps to AI strategy to complete a task	-
(III). How does coding work	-
8.Who is the father of Artificial Intelligence?	Alan Turing
9. What kind of jobs will not likely be replaced by Artificial Intelligence	(C)
A. Taxi driver	-
B. Warehouse worker	-
C. Computer Scientist (correct answer)	-
D. Customer service representative	-
10.Which of the following test can examine whether a machine is intelligent?	Turing Test
11.Which of the following is the reason for promoting the development of AI?	(D)
A. Big data, and increased computing power	-
B. The development of cloud network	-
C. The cost of hardware has lowered.	-
D. All of the above (correct answer)	-
12. Which of the following innovative applications is (are) promoted by Artificial intelligence and machine learning ?	(D)
A. Facial recognition	-
B. Natural language processing	-
C. Virtual assistants	-
D. All of the above (correct answer)	-
13.A simple Artificial Intelligence neural network has at least ____ layer(s)	Three
14. Which of the following applications uses AI technology?	(D)
A. Self-driving car	-
B. ChatGPT	-
C. Drawing Bot	-
D. All of the above (correct answer)	-
15. Which of the following is the main machine learning method used by Google Teachable Machine?	Supervised learning
16. Which method of Machine Learning is used for Alpha Go	Reinforcement learning
17. Which of the followings can be data sets of Artificial Intelligence?	(D)
A. Text, Words, Symbols	-
B. Image	-
C. Voice	-
D. All of the above (correct answer)	-
18. Put the event of machine learning in a correct order machine learning	3.1.2.4

1) Pattern recognition	-
2) Key features extraction	-
3) Data collection	-
4) Decision making	-
19. What should we consider when using AI applications?	(D)
A. The purpose and necessity of data collection	-
B. The protection of the personal data privacy	-
C. The safety storage of data	-
D. All of the above (correct answer)	-
20. Which of the following industries use AI-enabled applications?	(D)
A. Banking industry	-
B. Law and legal services	-
C. Human resources	-
D. All of the above (correct answer)	-
21. Which of the following is (are) the potential problem of AI-powered language model such as ChatGPT?	-
A. Accuracy problems	(D)
B. Discrimination and bias response	-
C. Plagiarism and cheating	-
D. All of the above (correct answer)	-
22. What does the “Confusing the AI project” help you to understand	(D)
A. Machine learning systems are not perfect or all-knowing	-
B. Unintentional bias are introduced by the training that human give them	-
C. It is important to have variation in training sets	-
D. All of the above (correct answer)	-
23. What does the “Biasing the AI project” help you to understand	(D)
A. Intentional bias are introduced by the training that human give them	-
B. The societal and ethical issues related to how AI systems are used	-
C. It is important to have a transparency and disclosure of how machine learning systems are trained	-
D. All of the above (correct answer)	-
24.What are the most common issues about Artificial Intelligence	(D)
A. Data Bias and injustice	-
B. Black box in nature	-
C. Require Big Data for potential exploitation of human and natural resources	-
D. All of the above (correct answer)	-
25.Which of the following tool(s) or application(s) can be used to create machine learning models	(C)
A. YouTube	-
B. Draw Bot	-

C. Machine learning for kids (https://machinelearningforkids.co.uk/) (correct answer)	-
D. Quick and Draw (https://quickdraw.withgoogle.com/)	-

Findings and Discussions

Summary of findings

The study's findings reveal the learning content of AI curriculum design from a holistic perspective with the appropriate pedagogical strategy and assessment mechanism in its implementation in primary school settings. First, this curriculum design has incorporated the domains of learning content, which are 1) Basic AI, 2) Machine Learning, 3) AI technologies such as teachable machines and 4) AI applications, 5) AI societal, ethical, and environmental implications through engaging students to learn AI literacy as well as 6) the AI thinking with the consideration of data justice and ethics in group projects. Previous studies reveal that AI foundations for knowledge (Chai et al., 2021; Lee et al., 2020), use and application of AI skills (Ho et al., 2019; Li & Song, 2019); the machine learning principles and application (Shamir & Levin, 2021; Toivonen et al., 2020), and AI thinking with data justice and ethics (Akgun & Greenhow, 2021; Melsion et al., 2021) are important learning content that should be included in AI education at the primary school level.

Second, the findings reveal that arts-based is an age-appropriate and engaging strategy often absent in AI literacy learning. At the same time, projects are often used to scaffold AI concepts such as rule-based if-then statements and big data concepts (Ho et al., 2019) and to demystify machine learning principles (Toivonen et al., 2020). It offers authentic experiences and promotes active learning, such as controlling a toy car on a physical track to learn about convolutional neural networks (Narahara & Kobayashi, 2018) and building a number-guessing robot to understand the optimization algorithm of machine learning (Ho et al., 2019). Toivonen et al. (2020) conducted a series of co-design machine learning projects with primary school students using teachable machine learning. These projects are well-received. The result validates that a teachable machine is an effective tool in teaching machine learning principles such as training data sets, prediction accuracy, and class labels, even for primary school students.

Thirdly, under the current primary landscape, self-report surveys (Chai et al., 2021; Dai et al., 2020), artifact-based assessments (Li & Song, 2019) and interviews (Lee et al., 2020; Ottenbreit-Leftwich et al., 2021) is often used in data collection procedures, whereas the use of games and competitions (Voulgari et al., 2021) has increased in data collection for assessment purposes. These studies reveal the inadequacy of rubric-based and evaluative mechanisms to analyze artifacts created by the students. Apart from Ali et al. (2019), who mentioned the Torrance test for assessment, only a few studies used pre- and post-test or knowledge measures (Rodríguez-Garciá et al., 2021; Toivonen et al., 2020) to assess the learning outcomes of AI literacy. To assess students' AI literacy, this study reveals that a mixed method, including interviews, artifacts assessments, pre- and post-questionnaires, and knowledge tests, could be used. It is expected that measurable applications, in conjunction with qualitative evidence of this assessment suggestion, can triangulate students' AI literacy learning across affective, behavioral, and cognitive domains.

Discussions

This study aims to design a holistic AI curriculum framework, as well as a pedagogical strategy and assessment method, to promote AI literacy among primary school students and inspire them to create projects using AI technology. Previous studies focus on AI learning tools and platforms such as Google Teachable Machine (Toivonen et al., 2020) and LearningML (Rodríguez-Garciá et al., 2020). Still, the design of AI curriculum and activities for young students have received less attention (Chiu & Chai, 2020). This study designs an AI curriculum with the inclusion of six modules, which are 1) Basic AI; 2) Machine Learning; 3) Teachable Machine; 4) AI Applications and Tools; 5) Group Arts-based Project; and 6) Group Presentation and Dialogic Learning. The proposed AI curriculum is believed to enhance students' AI knowledge and literacy skills. The collaborative nature of the arts-based learning approach helps students to develop 21st-century skills such as collaborative skills, communication skills, critical skills, and problem-solving skills (Colucci-Gray et al., 2019).

This study also designs an AI curriculum for primary education, which incorporates three main learning orientations: AI knowledge, skills, and AI thinking with data justice and ethics as well as its societal, ethical, and environmental impacts. Bozkurt et al. (2021), who reviewed studies of AI education from 1970 to 2020, showed a dearth of literature dealing with AI ethics. There should be a stronger emphasis on AI ethics in AI literacy education. This curriculum framework assists in the improvement of the teaching of AI ethics to young children to combat disinformation and bias (Kandlhofer et al., 2016), educate on AI-ethics issues (Ali et al., 2019), and embrace the value of human creativity (Ouyang & Jiao, 2021).

This study proposes various assessment methods with goals other than selection, specifically ensuring sustainable learning for work and life in the AI era (Miao, 2022) and bridging the learning gap by demonstrating needs. Furthermore, in addition to pre and post-tests for AI knowledge, the content suitability of AI curriculum surveys designed by the researcher and a diversity of assessment methods such as perception questionnaires, interviews, and artifact assessments may be considered.

Conclusion and Limitations

AI literacy education in the primary education context is still in its infancy. This study proposes future directions for researchers and educators by designing an AI primary education curriculum with the critical role of data in learning content, arts-based pedagogical strategy, teaching activities and learning tools, and assessment suggestions. It incorporates three main learning orientations: AI knowledge, skills, AI thinking for data justice, and attitudes, which allow students to meet the needs of the 21st century.

This study has two major contributions. First, by adding the new element of AI thinking with the considerations of data justice and ethics into the existing theoretical AI literacy framework, this research presents a holistic and inclusive AI curriculum for primary school students, with the considerations of all humans, non-humans, and nature. Second, this curriculum can demystify AI concepts and skills traditionally taught at secondary schools and universities. The educational implication is that it may empower students with the agency for critically

creating and evaluating AI models while considering minimizing any potential bias and its societal, ethical, and environmental implications. Since studies on AI curriculum in primary education are insufficient in the existing literature, this study serves as a valuable reference and guideline for future researchers. Furthermore, using a group arts-based pedagogical approach, this study empowers students with AI literacy, inspires them to create projects using AI technology, and be responsible AI citizens in the AI era of the twenty-first century.

This study presents a well-designed arts-based AI primary curriculum with an arts-based pedagogy and the inclusion of AI thinking for data justice to scaffold knowledge, skills, and attitudes to primary school students. However, there is no data to support the effectiveness of its implementation, nor does it provide results indicating reliability and validity. Although many researchers and governments have realized the importance of making AI literacy education accessible for all, the curriculum design still needs a rigorous examination and regular evaluation. Evaluation methods such as pilot testing, expert reviews, and external evaluation can help develop ways to enhance the pedagogical and instructional design of this proposed AI literacy curriculum.

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