Professional Development for Teachers in AI Literacy Education: Teaching Machine Learning to Senior Primary and Junior Secondary Students

Yin Yang[1][a] and Siu Cheung Kong[1,2*][b]
[1]Department of Mathematics and Information Technology, The Education University of Hong Kong, HKSAR, China
[2]Artificial Intelligence and Digital Competency Education Centre, The Education University of Hong Kong, HKSAR, China

Keywords: AI Literacy Education, K-12 Educational Settings, Machine Learning, Teacher Professional Development.

Abstract: This paper presents a study focused on equipping in-service teachers' skills of delivering courses on teaching machine learning concepts to senior primary and junior secondary school students. The pedagogical design of this study was based on the neuroscience-informed Attention-Engagement-Error-feedback-Reflection (AEER) framework. This study involved 36 in-service teachers from Hong Kong primary and secondary schools. We developed a model supported by Workshops, Discussions, and Resources (WDR) within the framework of Technological Pedagogical Content Knowledge (TPACK) to design the teacher professional development program. Data collection included pre- and post-tests on AI concepts, as well as pre- and post-questionnaires on using robots to teach machine learning on their TPACK, teachers' written feedback on the professional development. The findings suggest that the integration of using robots to teach machine learning and guided by a transdisciplinary pedagogical design AEER motivated teachers to teach AI literacy in senior primary and junior secondary schools. Furthermore, the workshops notably improved teachers' perceptions of their TPACK abilities. The implications for the professional development on equipping teachers for AI literacy education are summarised.

1 INTRODUCTION

In the rapidly evolving digital world, Artificial Intelligence (AI) has become a pivotal force in education. It is crucial that the next generation is not only adept at using these technologies, but also understands and shapes them. Thus, AI literacy emerges as a fundamental skill in the 21st-century educational settings (Casal-Otero et al., 2023).

While the integration of AI into educational settings presents vast opportunities, it also poses significant challenges, particularly in terms of curriculum development and teacher readiness for teaching machine learning in K-12 educational settings (Rauber et al., 2022; Sanusi et al., 2023).

Primary and secondary education systems often struggle to keep pace with technological advancements due to outdated teaching methods and a lack of professional development.

It is important for students to understand the mechanisms behind the technologies that permeate their daily lives. Educational initiatives that connect K-12 computing education with students' everyday technological interactions aim to close this gap (Gresse von Wangenheim et al., 2021; Touretzky et al., 2019; Van Mechelen et al., 2023).

Without a basic understanding of machine learning principles, many applications and services that children regularly engage with might seem inexplicable. For example, smartphones unlock with a glance at their owner's face; and home assistants respond to voice commands. It is essential to educate students that these functionalities, while sophisticated, do not equate to human-like intelligence (Karalekas et al., 2023). However, very limited studies have been conducted to guide teachers to teach AI for young learners (Su& Zhong, 2022).

This paper aims to address these challenges by examining a study focused on professional

[a] https://orcid.org/0000-0002-9966-248X
[b] https://orcid.org/0000-0002-8691-3016

Yang, Y. and Kong, S. C.
Professional Development for Teachers in AI Literacy Education: Teaching Machine Learning to Senior Primary and Junior Secondary Students.
DOI: 10.5220/0013200300003932

In *Proceedings of the 17th International Conference on Computer Supported Education (CSEDU 2025) - Volume 2*, pages 35-42
ISBN: 978-989-758-746-7; ISSN: 2184-5026

development for in-service teachers. This study contributes to the emerging field of AI education by demonstrating how innovative tools (e.g. AlphAI learning robots) and pedagogies can be effectively utilised in teacher professional development. The goal is to provide insights into scalable and sustainable approaches for augmenting AI literacy in foundational education settings. We designed the teacher professional development using the WDR (workshops, discussions, and resources)-supported TPACK model. A comprehensive 6-hour workshop was designed to deepen teachers' understanding of machine learning concepts and facilitate discussions on AI in transdisciplinary education, along with providing substantial teaching materials

The study is guided by two research questions:

Research question 1: How does professional development using the WDR-supported TPACK model affect teachers' understating of machine learning concepts?

Research question 2: How does professional development using the WDR-supported TPACK model affect teachers' ability of integrating learning robots with teaching machine learning?

2 LITERATURE REVIEW

2.1 Machine Learning in K-12 Educational Settings

The integration of machine learning in K-12 education is increasingly important as it prepares students for a technology-driven future. With the rapid advancement of AI technologies, understanding machine learning concepts is essential not only for future careers but also for fostering critical thinking and problem-solving skills. Studies have explored innovative approaches, such as teachable machines, which empower students to create and train their own machine learning models (Gresse von Wangenheim et al., 2021; Tedre et al., 2021).

However, despite these advancements, significant gaps remain in the widespread integration of machine learning education in K-12 settings. One major gap is the lack of comprehensive pedagogical framework accommodate the diverse educational needs across different educational standards (Yue et al., 2022). Our previous studies have proposed an innovative pedagogical framework, the Attention-Engagement-Error-feedback-Reflection (AEER) framework, specifically designed for teaching machine learning in primary schools (Kong & Yang, 2023; 2024a). These studies indicated that the AEER framework could significantly increase student motivation, engagement, and understanding of ML concepts.

Nevertheless, a notable challenge is that in-service teachers often lack the necessary training and confidence to effectively teach machine learning concepts (Antonenko & Abramowitz, 2023; Sulaiman et al, 2022).

2.2 Teacher Professional Development in Teaching Machine Learning

Among the limited studies, some have investigated various pedagogical tools and frameworks to equip teachers with the necessary skills to teach machine learning effectively (Lin & Van Brummelen, 2021). Other research has highlighted effective instructional methods, including project-based learning (Ossovski & Brinkmeier, 2019) and problem-based learning (Kim et al., 2021). The importance of teacher professional development cannot be overstated; well-trained educators are crucial for implementing effective ML curricula and fostering a supportive learning environment.

The framework of TPACK has been a comprehensive framework that identifies essential elements of teacher knowledge needed for successful technology integration in education (Koehler & Mishra, 2009; Mishra & Koehler, 2006). In this study, we focused on the four components: Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and the overarching blend of TPACK because the CK of machine learning is the focus for teaching in the professional development (Kong et al, 2020).

CK refers to the understanding of the subject matter that educators are teaching. For instance, a teacher must grasp key concepts in machine learning, such as K-nearest neighbours (KNN), artificial neural networks (ANN) (e.g., input layer, hidden layer, output layer, backpropagation), supervised learning, and reinforcement learning. Mastery of CK enables teachers to present information accurately and comprehensively, which is vital for student understanding. For example, knowing how to explain complex topics such as backward propagation and overfitting in supervised learning is essential for fostering student comprehension in these areas.

TCK involves understanding how technology can be effectively applied to teach specific subject matter. In the context of teaching machine learning, TCK includes the ability to manipulate the parameters of software platforms, such as using AlphAI robots in this study (https://learningrobots.ai/?lang=en). For instance, a teacher must know how to adjust settings to illustrate the workings of an ANN or to set up an environment for observing reinforcement learning.

PCK combines teaching strategies with subject matter knowledge. It involves knowing how to teach specific content effectively. For example, using the AEER pedagogy (refer to section 2.3, Kong & Yang, 2023; 2024a), a teacher can create lesson plans that encourage active participation, provide constructive feedback, and foster reflection among students.

TPACK is the synthesis of CK, PCK, and TCK. It represents a teacher's ability to integrate technology (AlphAI learning robots) into pedagogy while effectively conveying content knowledge. When teaching machine learning concepts, a teacher should not only have a strong grasp of the content and effective use of AEER pedagogical framework but also be proficient in using the AlphAI robots.

2.3 A Transdisciplinary Pedagogical Framework: Attention-Engagement-Error-Feedback-Reflection (AEER)

Teaching machine learning encourages educators to reflect on their instructional methods and how they facilitate students' ability to learn independently. Unlike machines, which rely on algorithms, humans possess a unique capacity for continuous learning (Chen & Liu, 2022).

In our ongoing research, we have refined the AEER framework originally proposed in earlier work (Kong & Yang, 2022; 2023). This framework has now been actively taught to in-service teachers in both primary and secondary educational settings. The AEER model — comprising Attention, Engagement, Error-feedback, and Reflection — aims to improve student AI learning experiences by integrating practical, hands-on activities using AlphAI learning robots.

Attention focuses on capturing students' interest through activities and relevant content. Teachers were taught to attract students' attention to identity the key information in learning. Engagement encourages active participation, allowing students to immerse themselves in the learning process. Error-feedback is a critical component where students learn to see mistakes as valuable learning opportunities. Students observed errors made by robots during training, such as hitting walls and getting stuck, and adjusted their strategies accordingly. The teachers guided students in understanding and rectifying errors made by the robots and helping them understand the importance of seeking for feedback in learning. This process not only helps students understand the iterative nature of machine learning but also the critical importance of feedback in learning.

Reflection is the final element where teachers guide students to reflect on what they have learned. This involves discussing the learning process, reviewing key concepts, and sharing experiences with peers to consolidate knowledge and insights.

The AEER pedagogical framework was used to guide teachers to teach machine learning concepts. At the same time, teaching machine learning provides students opportunities to reflect on learning. This framework transcends traditional educational boundaries. Teachers guide and facilitate, but they also learn from the students' experiences. In addition, the AEER framework encourages learning through failure, reflecting real-world scenarios where trial and error lead to innovation and discovery.

3 RESEARCH DESIGN

3.1 Research Procedure

The teacher professional development was guided by the WDR-supported TPACK model (Figure 1). The program includes six one-hour face-to-face training. The primary objective was to help teachers understand the concept of machine learning using AlphAI robots, the AEER pedagogical framework to deliver the workshops to primary school students. The professional development was supported by (1) face-to-face workshops: introducing AlphAI learning robots, KNN, ANN (e.g., input layer, hidden layer, and output layer), reinforcement learning, backpropagation, overfitting concepts, etc; (2) discussions on human-AI relations guided by the AEER pedagogical framework; and (3) available teaching resources and support provided by the research team.

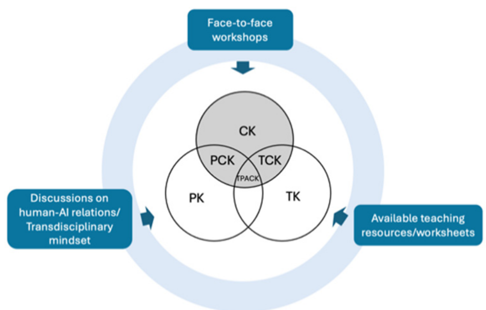

Figure 2: The WDR-supported TPACK model.

3.1.1 Face-to-Face Workshops

The face-to-face workshops serve as the core component of the professional development program, where teachers have hands-on activities with AlphAI learning robots (Figure 3). Teachers first learned about the functionalities of AlphAI robots, which are used as a tool to demonstrate and explore machine learning concepts (Figure 4). Detailed sessions on KNN (K-nearest neighbours), ANN (Artificial Neural Networks), and other algorithms such as reinforcement learning and backpropagation were introduced. Each session includes visual demonstrations and interactive activities to help teachers understand how these algorithms process data and learn. Teachers worked as a group to analyse how robots react to errors, learn about overfitting, and discuss strategies for optimising machine learning models.

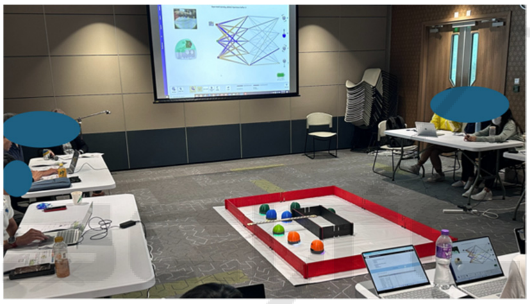

Figure 3: Teachers training the AlphAI learning robots in the face-to-face workshops.

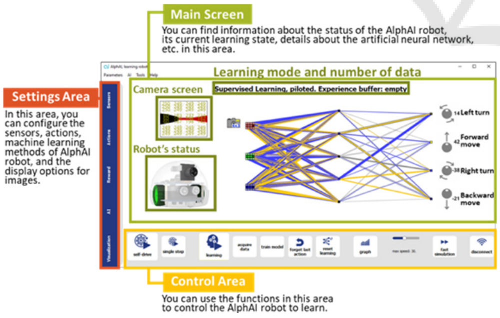

Figure 4: The interface of the AlphAI learning robot software visualising the ANN.

3.1.2 Discussions on Human-AI Relations

Guided by the AEER pedagogical framework, the discussions on human-AI relations aims to deepen teachers' understanding of AI's capabilities and limitations and to explore the ethical, social, and educational implications of integrating AI into the classroom. For example, backpropagation, a fundamental algorithm used for training neural networks, where the network learns from errors by adjusting its weights to minimise the difference between the actual output and the desired output. This method exemplifies the iterative and error-based learning process of AI, which contrasts significantly with human cognitive processes (Lillicrap et al., 2020). We believe these discussions are vital in the professional development programmes as they provide teachers with direct opportunities to shape how young minds understand and interact with AI technologies.

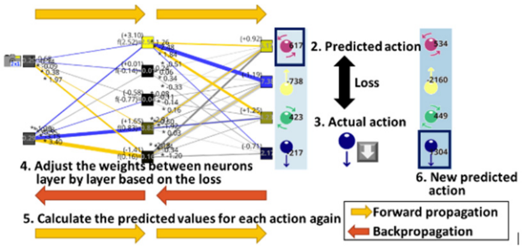

Figure 5: The illustration of backpropagation using AlphAI learning robots.

3.1.3 Available Teaching Resources

To facilitate the effective implementation of AI concepts in classrooms, teachers were equipped with a variety of teaching resources and support mechanisms provided by the research team. Figure 6 shows one page of the worksheets. In addition, the WhatsApp group was set up to allow the research team to provide ongoing support and updates for teachers to handle various teaching scenarios.

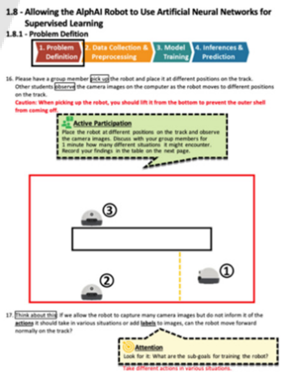

Figure 6: The interface of the AlphAI learning robot software visualising the ANN.

3.2 Participants

The purposeful sampling approach was adopted (Rai & Thapa, 2015). The teachers from the selected school had previously worked closely with the researchers on other research projects. They had at least three years of technology-enhanced teaching experience. Thirty-eight teachers (females = 34.2%, males = 65.8%) from seven primary schools and one secondary school participated. Signed consent forms were obtained from their schools and participants before the study. A total of 36 responses were returned. This study, guided by the TPACK model supported by the WDR and utilising the AEER pedagogical framework alongside AlphAI robots, specifically targeted teachers experienced in technology-enhanced teaching to explore the initial impact of integrating machine learning concepts into K-12 education.

3.3 Data Collection and Analysis

This study included both qualitative and quantitative data: (1) pre- and post-tests on machine learning concepts, (2) pre- and post-surveys on TPACK using a five-Likert scale (ranging from strongly disagree 1 to strongly agree 5), and (3) teachers' written reflections.

The machine learning concept test was designed to assess conceptual understanding in machine learning and deep learning (refer to Appendix I). The test was designed based on Bloom's taxonomy and comprised 13 items, with a Cronbach's alpha above 0.88. To be specific, for the knowledge and recall, two items tested students' ability to recognise and recall facts related to machine learning procedures. One item required students to identify the correct terminology for nodes in an ANN. One item involved recalling the definition of reinforcement learning. One item tested recall of the function and implementation of the backpropagation method in neural networks. For the comprehension, one item examined students' understanding of the machine learning process, particularly the application of supervised, unsupervised, and reinforcement learning. One item focused on comprehension of how the KNN based on the proximity of data points. Two items required understanding of the statement regarding supervised learning and unsupervised learning. Regarding the application, one item tested the ability to apply knowledge of supervised learning by selecting the most suitable method for robot navigation around obstacles. One item assessed the application of backpropagation to minimise errors in model predictions through iterative weight adjustments. One item involved applying knowledge to identify the best approach for creating a dataset to train an AI model to recognise different cats. One item focused on applying a simple computational technique, using a pre-trained CNN for recognizing flower types from images. For the analysis, one item involved analysing an image representation to determine if a model is exhibiting overfitting by evaluating differences in performance on training versus test data.

The questionnaire on TPACK includes 15 items across four aspects: TCK, CK, PCK, and TPACK (refer to samples in Appendix II). It was adapted from a validated version (Kong et al., 2024). Cronbach's alpha of four aspects is all above 0.89, indicating a good consistency of the instrument.

For the data analysis, descriptive data analysis and paired sample t-test and a Wilcoxon signed-rank test were used. For the RQ2, teachers' written feedback was also analysed to triangulate the results.

4 RESULTS

4.1 Machine Learning Concepts

A paired-samples t-test was used to determine whether there was a statistically significant mean difference in the conceptual understanding of the machine learning. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test. The total score of the machine learning concepts significantly increased, $M_{diff} = 3.91$, $SD = 2.62$, 95% CI = [3.03, 4.80] $t(35) = 8.96$, $p < .001$. Table 1 shows the descriptive data of each machine learning concept item.

Table 1: The descriptive data of machine learning concepts.

	Pre		Post	
	Mean	SD	Mean	SD
Item1	.61	.49	.97	.17
Item2	.61	.49	.97	.17
Item3	.75	.44	.92	.28
Item4	.58	.50	.97	.17
Item5	.47	.51	.97	.17
Item6	.64	.49	.92	.28
Item7	.75	.44	.92	.28
Item8	.69	.47	.94	.23
Item9	.36	.49	.61	.49
Item10	.67	.48	.86	.35
Item11	.81	.40	.92	.28
Item12	.28	.45	.42	.50
Item13	.19	.40	.94	.23

4.2 TPACK Survey

For the second research question, a Wilcoxon signed-rank test was employed because the TPACK data did not meet the normality assumption required for a paired-samples t-test. Table 2 shows the descriptive data of TPACK.

Table 2: The descriptive data of TPACK.

	Mean	SD	Skewness	Kurtosis
PreTCK	3.046	1.024	-.170	-.474
PreCK	2.956	.888	-.296	.238
PrePCK	2.840	.943	-.423	-.539
PreTPACK	2.833	.997	-.197	-.306
PostTCK	4.250	.745	-2.222	9.525
PostCK	4.222	.728	-2.282	10.242
PostPCK	4.243	.773	-2.051	7.852
PostTPACK	4.213	.781	-1.989	7.212

A Wilcoxon signed-rank test showed that there is a statistically significant change in teachers' perceived ability of TCK ($Z = 4.634$, $p < 0.001$), CK ($Z = 4.744$, $p < 0.001$), PCK ($Z = 4.782$, $p < 0.001$), and TPACK ($Z = 4.809$, $p < 0.001$). Figure 7 shows the bar chart of the comparison between pre-and post-survey.

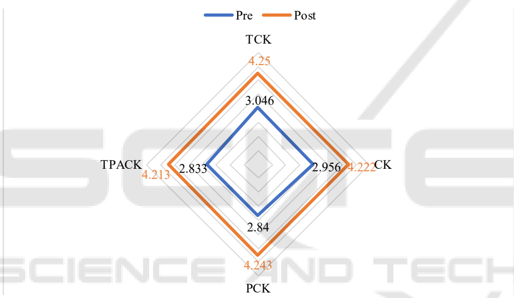

Figure 7: Teachers' pre- and post-perceived skills in TCK, CK, PCK, and TPACK.

4.3 Teachers' Reflections

Thematic analysis on participants' written feedback revealed several major themes on teachers' perceptions towards the training, including (1) enhanced machine learning concepts, (2) effective use of AlphAI robots under the AEER pedagogical framework to facilitate the teaching of machine learning concepts, and (3) strengthened confidence in teaching AI. One of the authors and a research assistant analysed the qualitative data. Initially, 30% of the data was coded collaboratively by both researchers to establish a consistent coding framework. After developing a shared understanding, each researcher independently coded the rest of the data. To assess the consistency of the thematic analysis between the two coders, interrater reliability was calculated after the independent coding phase. The reliability score was above 0.85, indicating a high level of agreement between the researchers. Any disagreements in coding were discussed and resolved through consensus. This study selected some examples from teachers written reflection.

Teachers noted that the detailed instructions provided during the course were particularly helpful. Firstly, the workshop clarified machine learning concepts, as Teacher B observed: "*The hands-on experience with the robots allowed me to really grasp how to explain complex concepts like neural networks in simple terms that my students can understand*."

Secondly, AlphAI learning robots were perceived as useful tools to help primary school students visualise the algorisms and neuro networks. Teacher F reflected, *"Using the AlphAI robots made it tangible for the students and for myself. It visualised a lot of preconceived notions about the complexity of machine learning"*. Another teacher highlighted the benefits of the AEER framework: "*What really stood out to me was the AEER framework. It is like we had a roadmap for engaging our students effectively, providing feedback, and then reflecting on it to make learning even better."*

Thirdly, teachers reported an increase in confidence regarding their ability to teach and integrate AI concepts into their curricula. As Teacher C reported: "*Honestly, I was a bit skeptical at first about how much I could really learn from just 6-hour workshop, but I am blown away! The way we were able to actually interact with the robots and see firsthand how the algorithms work—it is like a light bulb went off! I cannot wait to show my kids these concepts; they're going to love it.*"

Overall, the majority of teachers expressed satisfaction with the professional development workshops for teaching machine learning concepts. One teacher suggested, "*Can we do more of these workshops? The hands-on element, the clear explanations, the supportive atmosphere—it's exactly what we need to keep ourselves and our teaching methods up-to-date*." Teachers' written feedback showed the effectiveness of the training in enhancing teachers' capabilities to engage and educate their students on complex technological subjects.

5 CONCLUSIONS

This study provided significant insights into the efficacy of professional development workshops that utilised the AEER pedagogical framework and AlphAI robots in enhancing primary school teachers' understanding and teaching of machine learning concepts.

The research and practical implications of this study are discussed. First, the findings of this study contribute to the literature on educational technology by demonstrating how tangible tools such as AlphAI robots can demystify complex technological concepts like machine learning and neural networks. In addition, the effectiveness of the WDR-supported TPACK model highlights the need for structured yet flexible teacher professional development needs.

From a pedagogical perspective, the study reinforces the value of professional development in equipping teachers with not only the technical knowledge but also the pedagogical strategies necessary for integrating AI into K-12 educational settings. The increased confidence among teachers suggests that well-designed workshops can empower educators. Schools and educational policy makers should consider incorporating WDR-supported TPACK model in teacher training programs to ensure educators are well-prepared to meet the challenges of modern educational demands.

This pilot study on the use of AEER pedagogical framework and AlphAI robots in teaching machine learning concepts in K-12 education highlights the potential benefits of integrating pedagogical framework with robots (Camilleri, 2017).

The findings of the study also showed well-structured teacher professional development programs that incorporate both theoretical knowledge and practical applications can enhance teachers' confidence in delivering AI courses in senior primary and junior secondary schools. The confidence, an aspect of professional development is often overlooked but is essential for the practical application of new teaching strategies. Confidence in their own understanding allows teachers to creatively adapt AI teaching methods across various subjects, promoting a more integrated and innovative educational approach.

In conclusion, the workshop not only enhanced the teachers' understanding and ability to teach AI concepts but also significantly improved their pedagogical strategies, confidence, and enthusiasm for integrating technology into education.

This study highlights the critical role of teacher professional development in adapting education to the age of digital technology (Hu et al., 2023; Kong & Yang, 2024b). As AI continues to shape various sectors, the education sector must not fall behind. Professional development programs that incorporate current technologies and effective pedagogical strategies are essential for preparing teachers to facilitate an education that equips students with the necessary skills and knowledge to thrive.

The study, however, is limited by its short duration, and limited follow-up. Future research will involve longitudinal studies to track the sustained impact of these workshops on teachers' instructional practices over time. In addion, conducting studies across various educational contexts, including different school districts or countries, could provide insights into the scalability and adaptability of the AEER framework. This would also help identify contextual factors that influence the effectiveness of such technologies and frameworks in teacher education.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the funding from the Central Reserve Allocation Committee, The Education University of Hong Kong of the Hong Kong Special Administrative Region, China (Uncovering the "Black Box" of Machine Learning: Promoting Artificial Intelligence Literacy with AlphaAI robots in Senior Primary/Junior Secondary Schools across Hong Kong and France). (Project No. EdUHK 04A55).

REFERENCES

Antonenko, P., & Abramowitz, B. (2023). In-service teachers'(mis) conceptions of artificial intelligence in K-12 science education. *Journal of Research on Technology in Education*, *55*(1), 64-78.

Camilleri, P. (2017). Minding the gap. Proposing a teacher learning-training framework for the integration of robotics in primary schools. *Informatics in Education-an International Journal*, *16*(2), 165-179.

Casal-Otero, L., Catala, A., Fernández-Morante, C., Taboada, M., Cebreiro, B., & Barro, S. (2023). AI literacy in K-12: A systematic literature review. *International Journal of STEM Education*, *10*(1), 29.

Chen, Z., & Liu, B. (2022). *Lifelong Machine Learning*. Springer Nature.

Gresse von Wangenheim, C., Hauck, J. C., Pacheco, F. S., & Bertonceli Bueno, M. F. (2021). Visual tools for teaching machine learning in K-12: A ten-year systematic mapping. *Education and Information Technologies*, *26*(5), 5733-5778.

Hu, C. C., Yeh, H. C., & Chen, N. S. (2023). Teacher development in robot and IoT knowledge, skills, and attitudes with the use of the TPACK-based Support-Stimulate-Seek approach. *Interactive Learning Environments*, *31*(9), 5811-5830.

Karalekas, G., Vologiannidis, S., & Kalomiros, J. (2023). Teaching Machine Learning in K–12 Using Robotics. *Education Sciences*, *13*(1), 67.

Kim, S., Jang, Y., Kim, W., Choi, S., Jung, H., Kim, S., & Kim, H. (2021, May). Why and what to teach: AI curriculum for elementary school. In *proceedings of the AAAI Conference on Artificial Intelligence* (Vol. 35, No. 17, pp. 15569-15576).

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)?. *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60-70.

Kong, S. C, & Yang, Y. (2023). Designing and evaluating an Attention-Engagement-Error-Reflection (AEER) approach to enhance primary school students' artificial intelligence literacy and learning-to-learn skills: A pilot study. In *Workshop Proceedings of the 31st International Conference on Computers in Education ICCE 2023* (pp. 394-399). Matsue, Shimane, Japan: Asia-Pacific Society for Computers in Education.

Kong, S. C., & Yang, Y. (2024a). Using the robot-assisted attention-engagement-error-feedback- reflection (AEER) pedagogical design to develop machine learning concepts and facilitate reflection on learning-to-learn skills: Evaluation of an empirical study in Hong Kong primary schools. In *Proceedings of the 16th International Conference on Computer Supported Education - Volume 2* (pp. 155-162). Angers, France.

Kong, S. C., & Yang, Y. (2024b). A human-centered learning and teaching framework using generative artificial intelligence for self-regulated learning development through domain knowledge learning in K-12 settings. *IEEE Transactions on Learning Technologies, 17*, 1588-1599. https://doi.org/10.1109/TLT.2024.3392830

Kong, S. C., Lai, M., & Sun, D. (2020). Teacher development in computational thinking: Design and learning outcomes of programming concepts, practices and pedagogy. *Computers & Education*, *151*, 103872.

Kong, S. C., Yang, Y., & Hou, C. Y. (2024). Examining teachers' behavioural intention of using generative artificial intelligence tools for teaching and learning based on the extended technology acceptance model. *Computers and Education: Artificial Intelligence, 7,* 100328. https://doi.org/10.1016/j.caeai.2024.100328

Lillicrap, T. P., Santoro, A., Marris, L., Akerman, C. J., & Hinton, G. (2020). Backpropagation and the brain. *Nature Reviews Neuroscience*, *21*(6), 335-346.

Lin, P., & Van Brummelen, J. (2021). Engaging teachers to co-design integrated AI curriculum for K-12 classrooms. In *Proceedings of the 2021 CHI conference on human factors in computing systems* (pp. 1-12).

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017-1054.

Ossovski, E., & Brinkmeier, M. (2019). Machine learning unplugged-development and evaluation of a workshop about machine learning. In *International Conference on Informatics in Schools: Situation, Evolution, and Perspectives* (pp. 136–146). Springer.

Rai, N., & Thapa, B. (2015). A study on purposive sampling method in research. *Kathmandu: Kathmandu School of Law*, *5*(1), 8-15.

Rauber, M. F., & Gresse von Wangenheim, C. (2022). Assessing the learning of machine learning in K-12: A ten-year systematic mapping. *Informatics in Education*, *22*(2), 295-328.

Sanusi, I. T., Oyelere, S. S., Vartiainen, H., Suhonen, J., & Tukiainen, M. (2023). A systematic review of teaching and learning machine learning in K-12 education. *Education and Information Technologies*, *28*(5), 5967-5997.

Su, J., & Zhong, Y. (2022). Artificial Intelligence (AI) in early childhood education: Curriculum design and future directions. *Computers and Education: Artificial Intelligence*, *3*, 100072.

Sulaiman, S., Yu, H., Shaifuddin, N., Zamani, F. N., & Nordin, M. N. (2022). Instructors' perceptions about teaching machine learning in high school: a first step. *Mathematical Statistician and Engineering Applications*, *71*(3), 1667-1684.

Tedre, M., Toivonen, T., Kahila, J., Vartiainen, H., Valtonen, T., Jormanainen, I., & Pears, A. (2021). Teaching machine learning in K–12 classroom: Pedagogical and technological trajectories for artificial intelligence education. *IEEE Access*, *9*, 110558-110572.

Van Mechelen, M., Smith, R. C., Schaper, M. M., Tamashiro, M., Bilstrup, K. E., Lunding, M., ... & Sejer Iversen, O. (2023). Emerging technologies in K–12 education: A future HCI research agenda. *ACM Transactions on Computer-Human Interaction*, *30*(3), 1-40.

Yue, M., Jong, M. S. Y., & Dai, Y. (2022). Pedagogical design of K-12 artificial intelligence education: A systematic review. *Sustainability*, *14*(23), 15620.

APPENDIX I

Machine Learning Concepts
https://docs.google.com/document/d/1pysZ1PD48aMy6UOCmKknnt2ta07VRdb9QyDdHFkbqBM/edit?usp=sharing

APPENDIX II

TPACK Survey
https://docs.google.com/document/d/1U2TlnlvHHkeGiYfTXZBpjsSfirk6z9ufKjJ1TVUzYiM/edit?usp=sharing