Hong Kong-French Collaboration in Machine Learning Education for Junior Secondary Students: A Mixed-Methods Study on Teacher Development

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Abstract: *This exploratory mixed-methods study evaluates a teacher development (TD) workshop, jointly designed by Hong Kong and French educators, aimed at advancing machine learning (ML) literacy among French junior secondary teachers. The six-hour workshop, held in France, applied the TPACK framework and integrated AlphAI robots for hands-on ML activities. Quantitative and qualitative analyses revealed significant improvements in teachers' ML conceptual understanding and self-efficacy across all TPACK domains. Teachers reported substantial cognitive and affective growth, alongside greater confidence in utilising robots for ML instruction. They also highlighted implementation challenges, such as time and resource constraints. Ultimately, this study underscores the value of contextualised, experiential TD models and suggests scalable strategies for preparing teachers to deliver AI education in junior secondary settings.*

Keywords: *AI Literacy; Junior Secondary Student; Machine Learning; Teacher Development; TPACK*

1. Introduction

The rapid rise of machine learning (ML) and artificial intelligence (AI), exemplified by models like GPT, has fundamentally transformed the role of technology in society and education. However, the "black box" nature of ML algorithms raises pressing concerns regarding transparency and ethics, making ML literacy an urgent priority for K–12 education (Ng et al., 2021). Effective ML literacy must extend beyond basic technical skills to encompass critical thinking about bias, fairness, and broader societal impacts (Tedre et al., 2021; Kong et al., 2024).

Teachers are central to bridging this gap in ML understanding. Yet, they frequently lack adequate professional development and resources, particularly for teaching hands-on ML concepts (Gibellini et al., 2023). While robotics-integrated activities have proven effective in making abstract ML concepts tangible (Absalon & Deneux, 2025), scalable and effective teacher development (TD) approaches remain under-researched.

This study builds upon existing research from Hong Kong by adapting TD models and robotics-assisted learning for the French educational context. The collaborative workshop aimed to enhance teachers' conceptual mastery of ML and their pedagogical adaptation through context-sensitive approaches. The study is guided by three research questions:

RQ1: To what extent does the TD workshop enhance teachers' understanding of ML concepts?

RQ2: How does the TPACK-informed workshop influence teachers' ability to integrate learning robots into ML instruction?

RQ3: In what ways do teachers articulate their perspectives and experiences of the TD workshop?

2. Literature Review

AI's deep integration into daily life necessitates comprehensive ML literacy. Frameworks like Kong et al. (2024) highlight understanding, application, psychological readiness, and ethical reflection as key dimensions. Robot-assisted learning—such as with AlphAI robots—helps visualise ML algorithms (KNN, ANNs), supporting conceptual and ethical

learning (Absalon & Deneux, 2025). Success relies on teachers' ability to facilitate inquiry-based, ethical environments, demanding strong ML knowledge and adaptive pedagogy (Tedre et al., 2021; Gibellini et al., 2023).

Frameworks such as AEER (Attention-Engagement-Error-feedback-Reflection) and TPACK (Technological Pedagogical Content Knowledge) are vital for effective ML instruction. AEER provides a micro-level cycle for active learning, while TPACK aligns content, pedagogy, and technology (Kong et al., 2025). Professional Development (PD) programmes grounded in these frameworks—emphasising hands-on practice and peer collaboration—improve teachers' ML knowledge and self-efficacy. Sustaining impact requires ongoing support and adaptation across educational systems.

Scalable, contextually relevant TD models for ML are rare; most research prioritises student outcomes over teacher preparation. This study addresses these gaps by evaluating a joint Hong Kong-French TD workshop, offering insights into adaptable teacher preparation for ML education.

3. Research Design

3.1. Study Design and Participants

The study employed an exploratory mixed-methods design to assess a one-day TD workshop tailored specifically to the French secondary curriculum. This approach was chosen to thoroughly evaluate both the pedagogical coherence of the workshop and its feasibility for future, larger-scale interventions.

Eleven secondary teachers (72.7% male, 27.3% female) from nine schools in the Auvergne-Rhône-Alpes region participated. The cohort's ages ranged from 31 to 60, with the majority holding advanced degrees (63.6% Master's, 9.1% Doctorate) and possessing STEM backgrounds. This small sample size is reflective of the typical logistical constraints in exploratory, cross-cultural TD research.

3.2. Workshop Design

The six-hour workshop was grounded in TPACK and AEER frameworks, comprising:

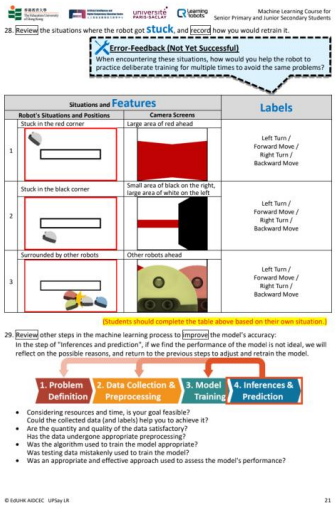
Workshops: Teachers utilised AlphAI robots and accompanying software to experiment training an ML model during playful "robot racing", and later visualise the details of KNN and ANN decision making.

Discussions: Guided by AEER, sessions focused on training data, robot performance, and ethical/societal issues.

Resources: Teachers received a comprehensive worksheet (110 pages, see Figure 1) and ongoing teaching support.

Figure 1

Sample worksheet page prompting students to analyse ML errors and consider alternative instructional strategies.



3.3. Data Collection and Analysis

Quantitative data included a 13-item ML concept test and a 15-item TPACK self-efficacy scale, both translated into French. Qualitative data comprised written reflections (N = 7) and semi-structured interviews (N = 2). Quantitative

analysis used Wilcoxon signed-rank tests; instrument reliability was high for TPACK (α = 0.94), but lower for the ML Concept Test due to sample size and instrument alignment (Taber, 2018). Qualitative data were analysed thematically.

4. Results

4.1. Enhancement in ML Conceptual Understanding (RQ1)

Teachers' ML concept test scores improved significantly, rising from a pre-test mean of 8.27 (SD = 1.68) to a post-test mean of 10.73 (SD = 1.49) out of 13 (Wilcoxon Z = -2.72, $p < 0.01$). Gains were most prominent in supervised learning, overfitting, and KNN/ANNs mechanics. Robotics activities were credited in teachers' qualitative reports for making abstract processes concrete, especially through real-time visualisation of data labelling and prediction.

4.2. Influence on Integrating Learning Robots (RQ2)

The TPACK-based activities substantially boosted teachers' self-perceived ability to integrate robots into their ML instruction. Wilcoxon signed-rank tests revealed significant pre-post gains across all measured domains (all $p < 0.01$). TCK (mean from 1.39 to 3.82, Z = -3.02), CK (2.11 to 3.93, Z = -2.94), PCK (1.98 to 3.43, Z = -2.85), and overall TPACK (1.36 to 3.36, Z = -2.95). These robust gains suggest that the robot-based tasks effectively helped teachers bridge the gap between technology, content, and pedagogy, thereby increasing their confidence in utilising innovative tools.

4.3. Teachers' Perspectives and Experiences (RQ3)

Thematic analysis of the qualitative data revealed three primary themes.

Cognitive growth. All respondents reported a deepened understanding of ML, with several noting an enhanced ability to break down and explain these concepts to students. The experience of "seeing a concrete application of AI usage with robots" was frequently highlighted as a catalyst for this growth.

Affective engagement. Teachers expressed high appreciation for the workshop's progressive, experiential design, valuing the safe environment it provided for trial-and-error. As one participant noted, "The progressivity allowed me to go gently," underscoring the vital role of pedagogical scaffolding.

Implementation challenges. Despite the positive feedback, teachers identified time constraints and classroom resource management as significant logistical barriers. Furthermore, some indicated a need to revisit highly complex topics, such as ANNs, to fully solidify their confidence prior to classroom implementation.

5. Conclusions and Implications

A focused, six-hour workshop guided by TPACK significantly enhanced French secondary teachers' ML conceptual understanding and self-efficacy in integrating robotics. Quantitative data showed substantial gains in ML literacy and TPACK domains; qualitative findings highlighted teachers' cognitive and affective growth, alongside practical concerns about classroom implementation.

Compared with the findings from Hong Kong (Yang & Kong, 2025), the French cohort had higher baseline ML scores and engaged in more technical discussions (they also teach at higher level). Both cohorts demonstrated strong TPACK gains and valued the hands-on, scaffolded approach. Contextual adaptation, such as focusing on core ML concepts relevant to the French curriculum, enhanced the training's impact.

Adaptable TD workshops should prioritise contextual relevance, feature customisable activities, and address logistical barriers through sustained support or digital platforms. Integrating these programmes into existing structures is critical for long-term viability. While the small sample size and lack of cross-context comparisons limit generalisability, the study provides a foundation for future, larger-scale research.

In summary, technology-enhanced, contextually grounded teacher development is essential for equipping educators to deliver rigorous ML literacy instruction. By addressing practical barriers and grounding training in robust frameworks like TPACK, teachers can effectively integrate AI technologies into junior secondary education and prepare students for an AI-driven future.

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) as well as the funding from the University Grant Council of the Hong Kong Special Administrative Region, China-France "PROCORE F-EdUHK801/24 Cultivating Learners to be Passionate Thinkers for AI-Human Partnership: A French-Hong Kong Knowledge Exchange" (Project No. EdUHK R9032).

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