Designing an AI Companion: Preservice Teachers Learning to Teach STEM with Robotics

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Abstract: Research shows that preservice teachers' self-efficacy to teach with technology impacts how they apply these technologies in classroom teaching practice. In many countries, elementary teachers are expected to teach all STEM subjects even though they have no undergraduate majors or minors in these subjects. Therefore, an important goal of Teacher Education is to enhance elementary preservice teachers' confidence to teach STEM subjects with technology such as Educational Robotics. This conceptual paper will report on the theoretical foundations and structural design features of an artificial learning companion (ALC) being integrated into VEX GO educational robotics (ER) activities to scaffold how preservice teachers learn to teach STEM with ER. The concept of an ALC is explained in terms of Vygotsky's Sociocultural Learning Theory, specifically the Zone of Proximal Development. Within this framework, generative AI will serve as an artificial companion to scaffold learning tasks such as programming code. While ALCs have been reported to enhance students' learning, motivation, and self-regulation, this paper responds to calls to explore ALCs as facilitators of learning by negotiation. Therefore, the design features used to develop the ALC are based on sociocultural learning theory, instructional scaffolding and prompt engineering design. With respect to the latter, the ALC functions as a responsive scaffold by offering task-specific support through questions, hints, feedback, and reflection. Instead of simply providing answers, the ALC will guide preservice teachers throughout the planning, creating, testing, and reflecting phases of activities with gradual reduction in support as preservice teachers' competence and confidence increase. This work extends scholarship in Computing Education and Teacher Education by illustrating how Gen AI learning companions can simultaneously support preservice teachers as learners of STEM and as future STEM instructors. The paper provides STEM teacher educators with a concrete, adaptable model for embedding AI scaffolds into robotics-based learning experiences to foster reflective and pedagogical thinking.

Keywords: Educational Robotics, Generative AI, STEM, Instructional Scaffolding, Teacher Education.

1. Background

Generative Artificial Intelligence (Gen AI) has prompted educators and researchers (e.g., Shin, Haudek, & Krajcik, 2025) to call for a reimagining of how STEM is taught and learned. The literature highlights the potential of Gen AI tools to personalize learning and reduce teacher workload (European School Education Platform, 2026; Yan et al., 2024). However, recent surveys indicate that teachers are experiencing challenges adopting and implementing Gen AI in teaching and learning. For example, Canadian teachers indicated that the expectation to keep up with Gen AI tools and how to use them ethically in learning is causing them to feel stress (Education Perfect, 2026); Thai teachers expressed the need for ethical guidelines (Tongchai & Malakul, 2026), and the most prevalent reasons reported by Australian teachers for not using Gen AI was lack of knowledge about how to use it (Collie & Martin, 2025). The preceding studies suggest that the adoption of Gen AI in schools has advanced more rapidly than teachers are being trained to use them. UNESCO (2024) argues that the successful integration of Gen AI in education requires a human-centred approach where teachers are trained to use these technologies in informed and responsible ways. There is therefore a need for curriculum-aligned AI tools and strategies that can guide teachers on how to use Gen AI for student learning.

With respect to teaching with technology, research shows that both in-service and preservice teachers' (PTs') self-efficacy to teach with technology directly influences how they integrate digital tools into classroom practice (Yildiz Durak et al., 2023; Zeng et al., 2022). Many countries, including South Africa and Canada, have introduced STEM in K–12 curricula that incorporate teaching with technology. In Ontario, Canada, the 2022 Science and Mathematics curricula require that elementary teachers teach STEM skills such as coding (Ontario Ministry of Education, 2022). Canadian elementary teachers, however, often lack undergraduate preparation in the STEM disciplines. Hence, in these Teacher Education contexts, science and mathematics methods courses must include learning activities that develop preservice teachers' confidence in teaching STEM content and skills using coding-related technology.

Educational robotics (ER) has been shown to support the development of STEM skills (Eguchi, 2021), deepen students' understanding of STEM concepts (Anwar et al., 2019), and enhance confidence, interest, and participation in STEM fields (Hudson et al., 2020). The aforementioned studies highlight the value of ER as a meaningful STEM learning activity in K–12 settings and for preservice teacher learning. This conceptual paper will examine the theoretical foundations supporting the development of a Gen AI artificial learning companion (ALC) and describe the design of a Gen AI ALC to be incorporated into VEX GO educational robotics (ER) activities. This Gen AI ALC will be implemented in a forthcoming study that will examine how Gen AI influences preservice teachers' confidence to teach STEM with ER.

2. Gen AI as a Metacognitive Scaffold

An ALC is more than a tool or an assistant; it involves students in reciprocal learning interactions (Chou et al., 2025). Prior research shows that ALCs can enhance learners' motivation, self-regulation, and conceptual understanding (Chou et al., 2025). Chou's paper calls for work that explores the use of ALCs as facilitators of learning through negotiation rather than as answer-providing tools. This paper is a response to this call. As such, an appropriate theory for conceptualizing the function and design of a Gen AI ALC is Vygotsky's (1978) Sociocultural Learning Theory, specifically the Zone of Proximal Development (ZPD). ZPD indicates the difference between what a learner can do independently and what the learner can achieve with assistance from an adult or more capable peers. Within the preceding framework, Gen AI will serve as the experienced adult to assist and scaffold students' learning how to program. The ALC will function as a responsive scaffold by offering task-specific support through questions, hints, feedback, and reflective prompts. Instead of simply providing answers, the ALC will guide preservice teachers throughout planning, creating, testing, and pedagogical reflection. Scaffolding also includes fading, where the instructor adjusts the supports and lessens or removes the support as the students' performance improves (Belland, 2017). The Gen AI scaffold will be designed to facilitate the gradual reduction of support as preservice teachers' competence and confidence increases. Preservice teachers will be asked to consult the AI scaffold when they need coding guidance, debugging support, conceptual explanations, and pedagogical feedback.

The AI scaffold will be built using a web-based interface on the OpenAI platform and will serve as a companion support tool for preservice teachers during the ER activity. Carefully designed prompts will serve as a metacognitive scaffold to support reasoning, problem-solving, and pedagogical reflection. Choi and Chang (2025) propose the following prompt engineering practices as important components for designing AI prompts supporting educational learning goals. Practices identified include incorporating domain-specific content, embedding critical thinking components (e.g., to justify, compare, evaluate), using clear and precise language, stimulating collaborative problem-solving, segmenting tasks into smaller components, organizing prompts logically for structured reasoning, and using iterative prompts for clarification and reflection prompts. These prompt engineering practices will be applied to design the Gen AI ALC for the VEX GO robotics (example activities found at https://codego.vex.com/).

3. Designing Gen AI Prompts for VEX GO Robotics Activities

The following examples illustrate the types of Gen AI prompts that will be created to support learning, metacognition and reflection during the VEX GO activities. During the "Drivetrain Moves and Turns" activity, the AI will help preservice teachers interpret the relationship between the code blocks and the robot's physical movement. For example, when they change a "drive for" or "turn for" value, the AI will prompt preservice teachers to predict what will happen, ask them to observe the movement and explain why the motion changed. The AI would not simply give them an answer; it would scaffold their reasoning. During the pseudocode-to-programming stage, the AI will help preservice teachers translate their planned sequence of movements into logical programming steps. For example, if a preservice teacher writes pseudocode for moving the robot in a rectangle, the AI will ask whether the sequence includes repeated forward movements and 90-degree turns, if the distance values are consistent, and whether the intended shape matches the expected path, serving as a metacognitive scaffold. During a "Turning Accurately" activity, the AI will support debugging and calibration through logical reasoning. If the robot does not turn as expected, the AI will guide preservice teachers to ascertain reasons, such as turn angle, wait time, surface friction, robot placement, or misunderstanding of the block behaviour. This is useful because robotics errors are often not only programming errors; they may also be due to features such as hardware setup, measurement, and positioning (Pivetti et al., 2026). During a parking challenge activity, the AI will support iterative design. Preservice teachers can describe their intended parking strategy, enter their pseudocode, or upload/describe their VEXcode block sequence. The AI will then provide

prompts such as: What movement should happen first? Where should the turn occur? How will you know whether the robot has moved too far? What should you change first if the robot overshoots the target position? Prompts such as, which sequence of activities do you think your future students will find the most challenging, would promote pedagogical reflection.

4. Implications for Theory and Teaching Practice

The paper offers an original contribution as it illustrates how a Gen AI ALC can be intentionally designed to support preservice teachers learn how to code and learn how to teach coding. This dual focus is particularly important in educational contexts, where non-STEM elementary teachers are expected to teach STEM. The Gen AI scaffold will serve as a model that preservice teachers can transfer and adapt for their own instructional use. The ready-to-use Gen AI scaffold with a scaffolding activity worksheet has the potential to reduce elementary teachers' stress around ethical AI implementation and enhance their confidence to integrate Gen AI to support metacognition and problem-solving among elementary students.

5. Conclusion

This work illustrates an application of Gen AI that promotes metacognition and learner agency rather than encouraging dependence on automated outputs. The Gen AI ALC is designed as an active, metacognitive support to scaffold the learning of STEM concepts and coding during ER activities. Its design is grounded in Vygotsky's ZPD and ethical principles for AI use, modelling a transparent and pedagogically grounded approach to AI use in learning and teaching.

Ethics Declaration

Not applicable.

AI Declaration

Google Search AI mode was used as a dictionary to clarify the meanings of the terms: metacognition, scaffold, and reasoning.

References

Anwar S, Bascou NA, Menekse M, Kardgar A. (2019) "A Systematic Review of Studies on Educational Robotics", *The Journal of Pre-College Engineering Education Research,* Vol 9, No**.** 2, pp 1-24.

Belland, B.R. (2017) *Instructional Scaffolding in STEM Education: Strategies and Efficacy Evidence*. Springer, Cham.

Choi, W. C., & Chang, C. I. (2025) "A Survey of Techniques, Key Components, Strategies, Challenges, and Student Perspectives on Prompt Engineering for Large Language Models (LLMs) in Education", *Preprints*.

Chou, C. Y., Chan, T. W., Chen, Z. H., Liao, C. Y., Shih, J. L., Wu, Y. T., & Hung, H. C. (2025) "Defining AI Companions: A Research Agenda--From Artificial Companions for Learning to General Artificial Companions for Global Harwell", *Research & Practice in Technology Enhanced Learning*, Vol 20, 1-45.

Collie, R.J., Martin, A.J. (2025) "Teachers' Early Uptake of GenAI In Teaching and Learning: Important Questions and Answers", *Soc Psychol Educ*, Vol 28, 93.

Education Perfect (2026) "The 2026 Canadian Teacher Experience Report: Teacher Experience, Digital Infrastructure, and Equitable Access". https://www.educationperfect.com/campaign/2026-canada-teacher-experience-report/

Eguchi A. (2021) "Theories and practices behind educational robotics for all", in Papadakis, S. & Kalogiannakis, M. (eds.) Handbook of Research on Using Educational Robotics to Facilitate Student Learning. Hershey, Pennsylvania, USA: IGI Global, pp 68-106.

European School Education Platform(2026) *Survey on artificial intelligence for teaching and learning*. https://school-education.ec.europa.eu/en/discover/surveys/survey-artificial-intelligence-teaching-and-learning#speaker-4113879

Hudson MA, Baek Y, Ching YH, Rice K. (2020) "Using a Multifaceted Robotics-Based Intervention to Increase Student Interest in STEM Subjects And Careers", *Journal for STEM Education Research*, Vol 3, pp 295-316.

Pivetti, M., Di Battista, S., Bozzi, G. et al. (2026) "What is a Programming Error? A Thematic Analysis of Teachers' Views on Errors", *Technology, Knowledge and Learning*, pp 1-23.

Shin, N., Haudek, K., & Krajcik, J. (2025) "The Potential of Using AI to Improve Student Learning in STEM: Now and in the Future, *Community for Advancing Discovery Research in Education (CADRE).*

Tongchai, A., Malakul, S. (2026) "Thai Teachers'Perceptions of Integrating Generative AI in K-12 Education: Opportunities and Challenges", *TechTrends*, Vol 70, pp 93–105

UNESCO, Miao, F. & Holmes, W.(2024) *UNESCO Guidance for Generative AI in Education and Research*. France: United Nations Educational, Scientific and Cultural Organization.

Vygotsky, L. S. (1978) *Mind in Society: The Development of Higher Psychological Processes*, Cambridge, MA: Harvard University Press.

Yan, L., Greiff, S., Teuber, Z. et al. (2024) " Promises and Challenges of Generative Artificial Intelligence for Human Learning", *Nat Hum Behav*, Vol 8, pp 1839–1850.

Yildiz Durak, H., Atman Uslu, N., Canbazoğlu Bilici, S., & Güler, B. (2023) " Examining the Predictors of TPACK for Integrated STEM: Science Teaching Self-Efficacy, Computational Thinking, and Design Thinking", *Education and Information Technologies*, Vol 28, No. 7, pp 7927-7954.

Zeng, Y., Wang, Y., & Li, S. (2022) "The Relationship Between Teachers' Information Technology Integration Self-Efficacy and TPACK: A Meta-Analysis". *Frontiers in Psychology*, 13,1091017.