Teacher-AI Complementarity: From Design to Implementation and Reflection

Pankaj Chejara, Kairit Tammets, Mart Laanpere, Annika Volt, Reet Kasepalu,
Edna Milena Sarmiento-Márquez and Linda Helene Sillat

Center of Education Technology, Tallinn University, Tallinn, Estonia

Abstract

Traditionally Artificial Intelligence (AI) was primarily focused on building adaptive tutoring systems that mimicked the role of teachers to deliver personalized instruction. Over time, AI applications have expanded to other domains, such as drop-out prediction and performance analytics, with a central goal of understanding and enhancing learning. This expansion has driven the growth of research fields like Educational data mining, Learning Analytics, and AI in Education. These fields have illustrated the potential of AI harnessing data from learning platforms and even from physical classroom spaces. Thus, AI can help teachers to efficiently observe and understand what is happening in their classrooms, augmenting the teacher's ability to maximize positive impact on learning. One emerging approach to achieving this synergy between humans and AI is hybrid intelligence, which emphasizes the collaboration and co-evolution of humans and AI. In this paper, we present our ongoing research efforts to design and develop educational technologies with an ability to evolve and adapt from their interactions with teachers and students, and align with human values and norms.

Keywords

Hybrid intelligence, Human-AI intelligence, Teacher-AI complementarity, Learning Analytics

1. Introduction

Technological advancements particularly in high-performance computing and big data, have enabled the generation and processing of vast amounts of learning traces -from student interactions with learning environments- with the purpose of enhancing student learning. Consequently, research fields such as Learning Analytics (LA), education data mining, and artificial intelligence (AI) in education emerged, demonstrating AI capabilities to harness learning data to extract patterns and insights from learning data. However, learning occurs within contexts, and without a holistic understanding, the full potential of those patterns and insights may remain unrealized.

As Akata et al. [1] note, human actions are always influenced by norms and values, which, even when not explicitly stated, shape what goals are considered acceptable and which actions are deemed appropriate. Therefore, to ensure that AI applications align with societal values, ethical principles, and legal frameworks, it is crucial to integrate human intelligence. This integration fosters a dynamic partnership between human and artificial intelligence, where teachers contribute their expertise in understanding contextual nuances, fostering relationships, and adapting to individual students' needs. Meanwhile, AI offers scalable data-driven insights, consistent monitoring, and personalized adaptations, all with the ultimate goal of enhancing learning experiences.

Emerging research has increasingly focused on the design of effective Teacher-AI partnerships in education, emphasizing its potential to enhance student outcomes by complementing teacher expertise with AI-driven insights and tools. Earlier studies such as Holstein and Aleven [2] highlight the promise of adaptive systems that empower teachers to make informed pedagogical decisions, while Molenaar [3] underscores the importance of integrating AI technologies in ways that align with teachers' instructional goals and classroom practices. This growing body of work illustrates the multifaceted nature of Teacher-

Joint Proceedings of LAK 2025 Workshops, co-located with the 15th International Conference on Learning Analytics and Knowledge (LAK 2025), Dublin, Ireland, March 03–07, 2025.
pankajch@tlu.ee (P. Chejara); kairit@tlu.ee (K. Tammets); martl@tlu.ee (M. Laanpere); annika.volt@tlu.ee (A. Volt); reetkase@tlu.ee (R. Kasepalu); msm@tlu.ee (E. M. Sarmiento-Márquez); sillat@tlu.ee (L. H. Sillat)

AI collaboration, which not only requires the development of sophisticated AI systems but also a deep understanding of teachers' needs, perceptions, and practices to ensure meaningful collaboration.

Teacher-AI collaboration can be viewed through the lens of complementarity, where teachers and AI systems bring distinct, yet synergistic strengths to the learning environment. However, research by Kim [4] has shown that while teachers recognize the potential of Teacher-AI collaboration to support instructional design, orchestrating teaching, professional development, and reducing grading workloads, several significant barriers remain. These include the lack of explicit and consistent curriculum guidance, the dominance of commercially driven AI systems in schools, the absence of clear ethical guidelines, and teachers' negative attitudes toward AI, all of which hinder the effective integration of AI into educational practices.

Earlier research has shown that to fully support teacher-AI complementarity, it is essential to design AI tools that make pedagogical models transparent for teachers, enabling them to trust and effectively use these tools in practice [5]. This includes the development and use of AI tools that adhere to specific pedagogical models and are integrated into teachers' professional development settings, ensuring that teachers receive expert-guided training to understand the pedagogical concepts underlying the data [6]. Furthermore, it is critical to focus on developing teachers' situation-specific skills, empowering them to not only notice relevant information provided by AI but also to interpret it in context and understand why certain student behaviors either foster or hinder learning and development [7]. This work aligns with the concept of teacher-AI complementarity by emphasizing the collaborative integration of human expertise and AI capabilities. Teachers rely on their pedagogical judgment and contextual understanding, while AI tools enhance their decision-making by providing transparent, data-driven insights based on pedagogical models. For this collaboration to succeed, teachers must be equipped with the skills to interpret AI-provided information and understand its pedagogical implications, creating a balanced partnership where the strengths of both: human intuition and machine intelligence are leveraged. This mutual enhancement underscores the importance of transparency, professional learning, and situation-specific skills in fostering effective teacher-AI complementarity. In this paper, we present three cases where we designed and implemented practices to support teacher-AI complementarity, focusing on the entire process - from design to implementation and reflection.

2. Three cases of teacher-AI complementarity

We present three use cases of teacher-AI complementarity, which are currently being developed by our research group, to improve teachers' understanding of how students' complex learning processes in mathematics or science can be supported.

2.1. EduFlex: Instructional trajectories and open learner models for flexible learning

This case is based on the premise that each student learns at a different pace, requiring a learning environment that supports personalized learning experiences. We argue that the design of instructional practices should account for students' individual characteristics - such as prior knowledge, self-regulation, and other skills to direct their knowledge in a flexible learning environment. Our approach [8] integrates three key components to support personalized and flexible learning experiences (figure 1): 1) a Domain model that provides the conceptual foundation for structuring learning content and outcomes; 2) an Authoring tool for creating flexible learning trajectories, through interactive learning materials in H5P, ensuring adaptability and engagement; and 3) Dashboards for both teachers and students, offering visualizations of learning paths and progress along the flexible trajectories, enabling reflection and informed decision-making. Together, these components facilitate a cohesive framework supporting individualized learning while maintaining teacher and learner autonomy.

The domain model for a specific subject is developed following the Estonian national curriculum. In this process, subject experts encode their domain knowledge in a machine-readable format, enabling integration with technologies to support flexible instructional trajectories. The instructional trajectories resulting from the domain model comprise a series of episodes, tasks, hints, and additional learning

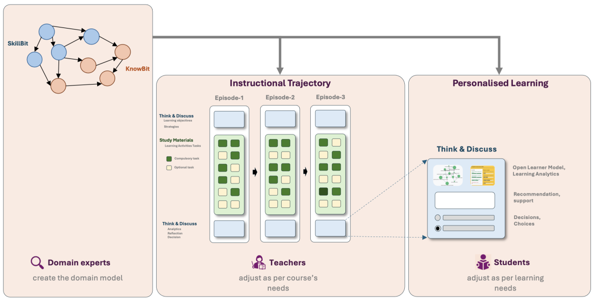

Figure 1: Conceptual framework for designing flexible instructional trajectories

resources. These trajectories are aligned with the principles of the 4C/ID model [9] meaning that tasks progressively increase their complexity to support the gradual development of skills. The episodes follow a predefined sequence based on the domain model, involving a structured suit of activities and content targeting a specific learning outcome. Additionally, students access further information through materials or hints, and are encouraged to reflect on their learning after completing each episode. The resulting learning path indicates the student's learning journey (i.e., actions, choices, and outcomes), summarized as an open learner model, developed using Bayesian modeling. This model enables students to make informed decisions about their learning, reflect on their progress, and adjust their strategies.

The tools were designed over three years, following a Design-Based Research (DBR) methodology in multiple phases. Each DBR phase involved evaluations with teachers and students. The evaluations with the teachers happened in the first phase, where they used ready-made learning resources and adapted them on a small scale. Despite their limited experience, they still found the tools beneficial for adding flexibility to the learning process. The students had mixed experiences: some benefitted from its ease of use, while others faced cognitive overload, reducing its efficiency.

The Teacher-AI complementarity is evident through a balanced partnership where technology supports teachers in understanding how students develop their competence. AI handles tasks such as tracking student progress, identifying learning patterns, and offering actionable insights by analyzing the relationships between skill acquisition and knowledge development. This allows teachers to focus on interpreting these insights to identify areas where students may need additional support or challenges, guiding their learning more effectively.

2.2. Kool-kit: Building a theoretically grounded technology to support teachers with learning design

The previous case argued the importance of designing flexible learning trajectories based on a domain model to support students' individual learning needs. However, designing a trajectory is only one phase as it is also important to formulate and sequence tasks and learning activities to foster deeper learning experiences and sustain cognitive engagement. Here, the ICAP framework [10] has been proven a valuable tool for helping teachers design learning experiences that encourage active, constructive, and interactive learning. However, creating an effective learning design (LD) integrating these principles in a classroom requires subject expertise, pedagogical knowledge, and technological proficiency - a combination potentially challenging for many teachers to achieve independently.

Addressing this need, we developed Kool-Kit, a suite of tools that uses large language models to provide a system grounded in the ICAP framework (figure 2). Kool-Kit supports teachers in designing lesson plans and creating H5P-based learning activities adjusted for their classrooms. The first tool in the suite is strongly based on ICAP to guide teachers in creating and refining lesson plans that promote different levels of engagement through chat-based interactions. The second tool offers an intuitive interface for specifying learning activities. Teachers can define the activity's summary, complexity level, and type (e.g., fill in the blanks, multiple-choice questions), and the tool generates H5P-based learning activities based on these inputs. These activities can then be downloaded and seamlessly

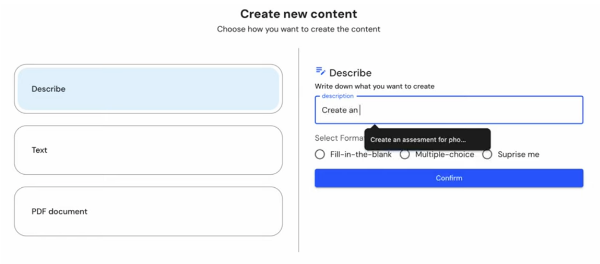

Figure 2: AI-assisted H5P-based learning content generator

integrated into any H5P-compatible learning environment (e.g., trajectory in Case 1). By simplifying the creation process, the tool hides the technical complexities of generating H5P elements while significantly speeding up the preparation of classroom activities. This makes it easier for teachers to design and implement engaging learning experiences that align with pedagogical principles and support student engagement. These tools are suitable for teachers from different subjects and school levels, as its foundational model focuses on the general principles of cognitive engagement. The initial prototype was developed collaboratively within the research group, addressing the practical need for supporting teachers in designing TEL practices that promote cognitive engagement. However, it has not yet been evaluated.

The teacher-AI complementarity in Kool-Kit lies in its ability to foster a mutual relationship between human and artificial intelligence. Kool-Kit harnesses AI to learn from teachers' experiences (earlier lesson plans and examples), adapting to their expectations and preferences, while simultaneously enabling teachers to benefit from AI's knowledge of learning sciences literature. This dynamic interaction allows teachers to advance their pedagogical knowledge, refine their teaching strategies, and design more effective learning experiences.

2.3. CoTrack: Supporting teachers with monitoring and intervention during collaborative learning activities

The third case extends the focus on designing learning experiences to support students' complex thinking skills and understanding their progress, recognizing that learning is a dynamic, collaborative process. Collaboration is a multifaceted skill involving components such as argumentation and cooperation, which require deliberate practice and teacher awareness of student activities during collaborative tasks. Monitoring students' interactions, particularly in blended settings that combine face-to-face collaboration with digital tools, presents significant challenges for teachers and underscores the need for robust tools to aid collaboration monitoring.

To address this, we developed CoTrack, a multimodal LA tool designed to support teachers in monitoring and co-regulating collaboration in classrooms. CoTrack is a web-based application that provides a collaborative writing space for group participants and captures audio, video, and log data to monitor their interactions. One of its key features is the real-time analysis of collaboration quality, using data from these sources to estimate and visualize group dynamics [11, 12]. The tool integrates a dashboard (figure 3) displaying participants' speaking and writing contributions alongside predictive analytics of collaboration quality. Additionally, CoTrack employs a rule-based intervention engine informed by learning sciences literature, offering intervention strategies for teachers to support students. This real-time support enables teachers to better understand group dynamics, identify areas needing intervention, and foster the development of collaborative skills.

CoTrack was developed through DBR methodology involving three iterations with more than 50 in-service teachers over 5 years [13, 14]. It can be used for teaching and research purposes as well. CoTrack is suitable for face-to-face collaboration activities requiring a shared writing space and for capturing audio and video data for post-hoc reflection and analysis. Its usability evaluation showed that teachers found CoTrack easy to use and useful for monitoring collaboration activities [14]. CoTrack

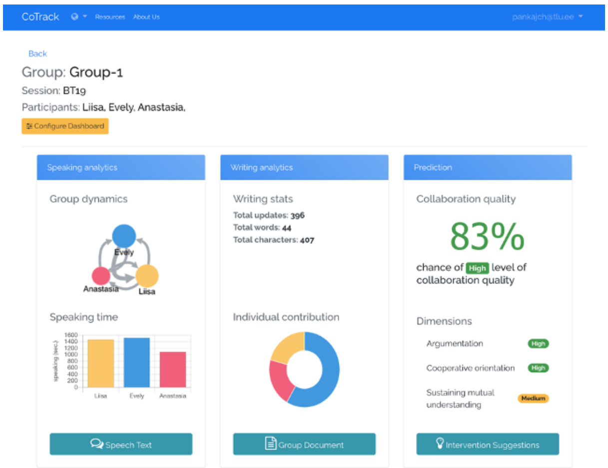

Figure 3: CoTrack real-time dashboard

has been applied across various subjects (e.g., Mathematics, Biology) and school levels, highlighting its adaptability to various contexts.

The teacher-AI complementarity in the third case is realized through the collaborative partnership between teachers and CoTrack, which supports teachers by providing real-time insights into students' collaborative processes, analyzing complex multimodal data (audio, video, and logs) to estimate collaboration quality and identify potential issues. These AI-driven analytics enable teachers to focus on interpreting the data and making informed decisions about when and how to intervene effectively. At the same time, teachers bring their contextual expertise to the table, tailoring interventions to the unique needs of their students and classroom dynamics. This collaboration ensures that while CoTrack provides objective and data-driven monitoring, the teacher retains the essential role of adapting actions to foster meaningful learning experiences.

3. Conclusion

The three cases presented demonstrate how AI tools can complement the teacher's role by influencing their skills, knowledge, attitudes, and tasks in distinct ways. The first case highlights the importance of integrating domain models enhancing teachers' content and domain knowledge and their ability to design flexible learning trajectories. The second case, through the Kool-Kit suite, emphasizes the development of teachers' pedagogical and technological skills, knowledge, and capacity to create and implement H5P-based activities, based on the ICAP framework. The third case, with CoTrack, showcases how AI can support teachers in monitoring complex collaborative processes, enhancing their situational awareness and decision-making skills in real-time classroom settings. Collectively, these cases demonstrate how teacher-AI collaboration can redefine instructional tasks by automating routine elements, offering evidence-based insights, and enabling teachers to engage in higher-order activities, such as interpreting data within the framework of pedagogical concepts, adapting learning designs, and providing support to students. This highlights the potential of teacher-AI complementarity to shape teachers' professional learning but also enriching the learning experiences for students.

Acknowledgments

This research was supported by the Estonian Ministry of Education and Research under the research project ÕLHAR1: "Flexible Learning Paths for Supporting Learner-Centered Learning in Schools", and by the Estonian Research Council's Personal Research Grant (PRG) under grant number PRG1634

References

[1] Z. Akata, D. Balliet, M. De Rijke, F. Dignum, V. Dignum, G. Eiben, A. Fokkens, D. Grossi, K. Hindriks, H. Hoos, et al., A research agenda for hybrid intelligence: augmenting human intellect with collaborative, adaptive, responsible, and explainable artificial intelligence, Computer 53 (2020) 18–28.

[2] K. Holstein, V. Aleven, Designing for human–ai complementarity in k-12 education, AI Magazine 43 (2022) 239–248.

[3] I. Molenaar, Towards hybrid human-ai learning technologies, European Journal of Education 57 (2022) 632–645.

[4] J. Kim, Types of teacher-ai collaboration in k-12 classroom instruction: Chinese teachers' perspective, Education and Information Technologies (2024) 1–33.

[5] T. Ley, K. Tammets, G. Pishtari, P. Chejara, R. Kasepalu, M. Khalil, M. Saar, I. Tuvi, T. Väljataga, B. Wasson, Towards a partnership of teachers and intelligent learning technology: A systematic literature review of model-based learning analytics, Journal of Computer Assisted Learning 39 (2023) 1397–1417.

[6] K. Tammets, T. Ley, Integrating ai tools in teacher professional learning: a conceptual model and illustrative case, Frontiers in Artificial Intelligence 6 (2023) 1255089.

[7] R. Kasepalu, M. Saar, K. Tammets, Exploring situation-specific skills to boost teachers' use of analytics, in: R. Ferreira Mello, N. Rummel, I. Jivet, G. Pishtari, J. A. Ruipérez Valiente (Eds.), Technology Enhanced Learning for Inclusive and Equitable Quality Education, Springer Nature Switzerland, Cham, 2024, pp. 179–192.

[8] A. Volt, M. Laanpere, J. Kurvits, Supporting flexible learning paths with interactive learning resources in mathematics: lessons learned, Educational Media International (2024) 1–16.

[9] J. J. Van Merriënboer, P. A. Kirschner, Ten steps to complex learning: A systematic approach to four-component instructional design, Routledge, 2017.

[10] M. T. Chi, R. Wylie, The icap framework: Linking cognitive engagement to active learning outcomes, Educational Psychologist 49 (2014) 219–243.

[11] R. Kasepalu, P. Chejara, L. P. Prieto, T. Ley, Studying teacher withitness in the wild: comparing a mirroring and an alerting & guiding dashboard for collaborative learning, International Journal of Computer-Supported Collaborative Learning 18 (2023) 575–606.

[12] P. Chejara, R. Kasepalu, L. P. Prieto, M. J. Rodríguez-Triana, A. Ruiz Calleja, B. Schneider, How well do collaboration quality estimation models generalize across authentic school contexts?, British Journal of Educational Technology 55 (2024) 1602–1624.

[13] P. Chejara, L. P. Prieto, M. J. Rodriguez-Triana, R. Kasepalu, A. Ruiz-Calleja, S. K. Shankar, How to build more generalizable models for collaboration quality? lessons learned from exploring multi-context audio-log datasets using multimodal learning analytics, in: LAK23: 13th International Learning Analytics and Knowledge Conference, LAK '23, ACM, New York, NY, USA, 2023, p. 111–121.

[14] P. Chejara, R. Kasepalu, L. Prieto, M. J. Rodríguez-Triana, A. Ruiz-Calleja, Bringing collaborative analytics using multimodal data to masses: Evaluation and design guidelines for developing a mmla system for research and teaching practices in cscl, in: LAK24: 14th International Learning Analytics and Knowledge Conference, LAK '24, ACM, New York, NY, USA, 2024, p. 800–806.