Editorial for the Special Issue: EduRobotX 2025 – Innovations and Applications of Educational Robots and Robotics*

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1. Introduction

The 2nd International Workshop on Educational Robots and Robotics, organized by the EATEL Special Interest Group EduRobotX and held during the European Conference on Technology Enhanced Learning (EC-TEL) 2024 in Krems, Austria, aligned closely with the conference's overarching theme of inclusive and equitable quality education for all. This workshop specifically emphasized educational robots and robotics as tangible, embodied, and interactive technologies that enrich learning experiences within physical spaces, foster learner curiosity, and accommodate diverse learner needs.

Extensive research has demonstrated that educational robots and robotics can significantly enhance student motivation, engagement, curiosity, learning outcomes, attitudes, experiences, computational thinking, collaboration, and creativity across a broad spectrum of educational contexts, spanning from primary to tertiary levels [1–6]. The EduRobotX workshop aimed to advance the goal of inclusive and equitable education by exploring the varied applications of educational robots and robotics across

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different learning environments and age groups. Key thematic areas of interest included: (1) Robot-Assisted Language Learning (RALL), where educational robots support second language acquisition (SLA) and have shown particular effectiveness with elementary school students [7]; (2) Robot-Supported Collaborative Learning (RSCL), involving robots as complementary facilitators alongside teachers to improve learning environments in higher education [8]; and (3) hybrid learning utilizing telepresence robots, which enable remote learners, such as children in hospitals or individuals with mobility limitations, to participate synchronously in classroom activities while maintaining social connectivity [9]. Through these focal points, the workshop reflected on contemporary practices, empirical research, and their implications for pedagogically sound integration of robots and robotics in educational settings. The scope of the EduRobotX workshop extended beyond traditional classrooms to include all age groups, from preschool children who benefit from robots supporting sequencing and logical thinking through tangible programming, to senior learners engaging in individualized cognitive and collaborative learning activities. Furthermore, the workshop underscored the potential of educational robotics in special education, exemplified by using robots to support autistic learners in developing social and communication skills, enhancing interpersonal interactions, reducing stress, and maintaining attention [10]. This event fostered the exchange of innovative approaches, didactic frameworks, empirical findings, and practical use cases across diverse educational contexts.

2. Themes of this Special Issue

Over the past decade, educational robots and robotics have transitioned from niche experimental tools to more widespread applications across diverse educational contexts. Beyond conventional use in school and higher education, these technologies have demonstrated promising applications in early childhood education, for example, to foster computational thinking and programming skills [11], as well as to prepare pre-service teachers for integrating educational robots into early learning settings [12]. Additionally, educational robots have been employed to support older populations by enhancing information and communication technology (ICT) skills among senior citizens [13] and to assist immigrant learners through Robot-Assisted Language Learning (RALL) interventions [14]. The contributions in this special issue encompass a wide spectrum of themes, spanning from fostering computational thinking in early childhood education, empowering educators in school settings, and engaging university students, to addressing the digital divide and promoting social inclusion among older adults.

As highlighted by the authors within this volume, the deployment of educational robots across various contexts offers numerous potential benefits but also presents significant challenges. For instance, in early childhood education, the introduction of robots such as Bee-Bots can substantially increase learner engagement and support computational thinking development. However, even these relatively simple and playful robots require careful curricular integration and active educator facilitation to ensure meaningful learning experiences and outcomes [15]. Similarly, while humanoid robots such as NAO have demonstrated effectiveness in reducing technology anxiety and fostering digital literacy confidence among older adults, human oversight and adaptive instructional strategies remain crucial to address learners' apprehensions and facilitate successful technology adoption [16].

Collectively, the studies presented in this special issue challenge the notion that educational robots can unilaterally revolutionize education or serve as panaceas for systemic challenges, such as teacher shortages. Rather, these contributions underscore the need for appropriate pedagogical frameworks, sustained human facilitation, and inclusive design principles to guide the integration of educational robotics into learning environments. For example, while robotics integration in STEM teacher professional development holds promise for alleviating anxiety and enhancing self-efficacy, its sustained impact is contingent upon institutional support and allocation of adequate resources [17].

Trust in human-robot collaboration emerges as a critical theme throughout this issue. As demonstrated in the study by [18], users' trust in robotic capabilities correlates with greater adherence to robot-guided decisions, whereas distrust may lead to rejection of these recommendations. Two studies focus on robotics in higher education contexts, one investigating humanoid robots and the other telepresence robots. The study on humanoid robots in higher education [19] reveals their potential as supplementary teaching aids that enrich university pedagogy by offering unique benefits such as constant availability and classroom management support. Additionally, smaller group sizes appear to facilitate more positive perceptions due to increased interaction, although this raises important scalability concerns [19]. The study on telepresence robots [20] highlights positive experiences reported by both in-class and remote students, suggesting that telepresence robots can enhance student engagement and learning outcomes. However, the study also identifies ongoing technical challenges, including network connectivity, audio clarity, and screen visibility limitations.

Finally, generative Artificial Intelligence (genAI) represents another significant topic in this special issue. Educational robots augmented with generative AI capabilities can serve as dynamic conversational agents, accommodating diverse learning styles, multilingual classrooms, and special education needs. While the integration of Large Language Models (LLMs) with educational robotics opens promising pathways toward adaptive and inclusive education, it concurrently raises important concerns related to the quality of information, cognitive load, ethical considerations, and the balance between automated support and essential human interaction [21].

3. Papers in this Special Issue

This special issue, Innovations and Applications of Educational Robots and Robotics, brings together seven diverse studies that investigate the transformative potential of educational robots and robotics across a range of contexts. These contexts include early childhood education, STEM training in schools, social and digital inclusion of older adults, collaborative learning in higher education, and the overarching topic of the integration of large language models (LLMs) with educational robots to foster adaptive, learner-centered environments. Each contribution offers a distinct perspective on the applications of educational robots:

1. **Fostering Computational Thinking in Early Childhood Education**: The study titled "Integrating Programmable Robots to Foster Computational Thinking in Early Childhood Classrooms" reports on an intervention using *Bee-Bot* robots with 3-year-old children to cultivate foundational computational thinking skills [15].
2. **Bridging the Digital Divide with Robots**: The study titled "Enhancing Social Inclusion Among Older Adults Through *NAO* Robot-Assisted Digital Literacy Programs" explores how humanoid robots such as *NAO* can facilitate older adults' acquisition of digital literacy skills—specifically using *Instagram*—to promote social inclusion [16].
3. **Empowering Teachers in STEM Education**: The paper "STEM Education with Robotics Activities: A Task-Centered Teachers' Professional Development Program" examines how a professional development program employing *LEGO* Mindstorms enhances STEM teachers' confidence and competence in integrating robotics within their curricula [17].
4. **Building Trust in Collaborative Human-Robot Interaction:** The paper "Building the Mental Model with Trust in Human-Robot Collaboration" investigates the role

of trust in collaborative tasks, utilizing augmented reality alongside robotics to create immersive and effective learning experiences [18].

5. **Humanoid Robots in Higher Education:** The study “Exploring the Influence of Group Size and Interaction Rate on Students’ Perceptions of Humanoid Robots in Higher Education” examines how variables such as group size and interaction frequency influence students’ perceptions of robots like *NAO* relative to human instructors [19].
6. **Telepresence Robots (TR) in Higher Education (HE):** The study "Exploring Greek students’ intention to use Telepresence Robots in Higher Education" presents findings from pilot studies assessing experiences, acceptance, and effects of telepresence robot usage among university students in Greece [20].
7. **AI-Driven Personalized Learning:** The paper “Personalized Learning Artificial Intelligence: Exploring Multimodal Social Robotics in the Classroom” delves into the integration of large language models with humanoid robots to develop adaptive, personalized learning environments tailored to individual learners’ needs [21].

Collectively, the papers in this special issue illuminate the promising opportunities that educational robots and robotics can afford, while critically addressing the challenges and limitations inherent in their implementation. They underscore that, although technology can significantly empower educators and learners, its true value depends on thoughtful integration within meaningful, inclusive, and pedagogically grounded educational practices.

4. Conclusions and Future Directions

This special issue reinforces that educational robots and robotics are not silver bullets for all educational challenges. Instead, they constitute powerful tools that, when thoughtfully integrated, can foster collaboration, curiosity, creativity, diversity, and inclusion. These technologies enrich learning environments by making them more tangible, interactive, and engaging. These are the qualities that are especially critical in counterbalancing the often abstract and disembodied nature of purely digital education. By enabling learners of all ages and backgrounds to actively participate and connect in meaningful ways, educational robotics and robots contribute to the broader goal of inclusive and equitable quality education for all. However, the future trajectory of educational robotics and robots hinges on effectively addressing several critical challenges mentioned by the authors of the papers in this special issue:

1. Equity and Access: It is imperative to ensure that robotics technologies are inclusive and accessible to all learners, irrespective of socioeconomic background, age, gender, geographical location, or individual abilities. As evidenced in this special issue, applications range widely, from early childhood education fostering foundational computational thinking [15] to supporting older adults in bridging the digital divide through robot-assisted digital literacy [16]. Closing access gaps remains essential to realizing the full potential of educational robots and robotics.

2. Ethical Design and Implementation: Alongside technological advances, we must carefully navigate concerns related to data privacy, algorithmic bias in AI-enabled robots, and the potential risks of depersonalizing education through excessive automation. Integrating Large Language Models (LLMs) with educational robots [21], for example, offers promising avenues for personalized and adaptive learning, yet raises important ethical questions around cognitive load, autonomy, and human-robot interaction dynamics.

3. Sustainability and Scalability: The integration of educational robots must be sustainable and scalable across diverse educational contexts. Professional development programs for teachers [17], effective facilitation in early childhood classrooms [15], and robust support for human-robot collaboration that builds trust [18] all illustrate the necessity of thoughtful pedagogical frameworks and institutional commitment. Moreover, technical and infrastructural challenges, such as connectivity issues encountered with telepresence robots in higher education [20], highlight the need for practical, resource-efficient implementation models.

In conclusion, the papers presented here collectively emphasize the indispensable role of human facilitation, pedagogical grounding, and inclusive design. Robots, whether humanoid, telepresence, or AI-augmented, are most effective when positioned as complements, not substitutes, to educators and learners. This balanced perspective highlights the promise of educational robotics while realistically acknowledging current limitations, such as scalability, trust, and ethical considerations.

We invite readers to engage with the diverse empirical findings and didactic approaches shared throughout this special issue. We hope that this collection inspires not only new ideas and critical reflection but also actionable innovations that push the boundaries of what educational robots and robotics can achieve. By continuing this conversation, educators, researchers, and practitioners can collectively advance the field, ensuring

these technologies serve as catalysts for richer, more inclusive, and equitable learning experiences worldwide.

Declaration on Generative AI

During the preparation of this work, the author(s) used Grammarly for the spelling check.

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