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EARLY CHILDHOOD EDUCATION IN 2075: A CONCEPTUAL FRAMEWORK AND PLAUSIBLE DEVELOPMENT SCENARIOS

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Abstract/Izvleček

This paper explores possible developmental trajectories of early childhood education toward 2075 using a conceptual foresight approach. Drawing on research in pedagogy, neuroscience, artificial intelligence, and educational technology, it proposes an integrated framework for future learning environments. The analysis suggests that sensor technologies, AI-supported systems, and neurobiological approaches may enhance personalised learning while strengthening the integration of physical, cognitive, and emotional development. Despite technological advances, early childhood educators remain central in creating meaningful learning experiences, supporting children's holistic development, and safeguarding the humanistic and ethical foundations of education.

Keywords:
early childhood education; foresight; artificial intelligence; neuroscience; physical education.

Predšolska vzgoja leta 2075: konceptualni okvir in verjetni scenariji razvoja

V prispevku s pomočjo konceptualnega pristopa strateškega predvidevanja (angl. *foresight*) raziskujemo možne smeri razvoja predšolske vzgoje do leta 2075. Na podlagi raziskav s področij pedagogike, nevroznanosti, umetne inteligence in izobraževalne tehnologije predlagamo integriran okvir za prihodnja učna okolja. Analiza nakazuje, da bi lahko senzorske tehnologije, sistemi s podporo umetne inteligence in nevrobiološki pristopi izboljšali personalizirano učenje, hkrati pa okrepili povezovanje gibalnega, kognitivnega in čustvenega razvoja. Kljub tehnološkemu napredku vzgojitelji predšolskih otrok ostajajo ključni pri oblikovanju smiselnih učnih izkušenj, podpiranju otrokovega celostnega razvoja ter varovanju humanističnih in etičnih temeljev izobraževanja.

Ključne besede:
predšolska vzgoja, strateško predvidevanje (*foresight*), umetna inteligenca, nevroznanost, gibalna vzgoja

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Introduction

Early childhood education is continuously evolving in response to social, technological, and cultural changes. Reflections on the future of education are increasingly informed by contemporary research and emerging trends in pedagogy, psychology, technology, and societal development (UNESCO, 2021; Miao et al., 2021; OECD, 2024; UNESCO, 2025).

Although numerous studies have examined individual aspects of artificial intelligence, digital technologies, neuroscience, and personalised learning (Luckin, 2022; Holmes et al., 2023; Zawacki-Richter et al., 2024), considerably fewer have integrated these developments into a comprehensive conceptual framework aimed at the long-term evolution of early childhood education. It is within this research gap that the present study proposes a novel foresight model synthesising current scientific knowledge and plausible developmental trajectories toward the year 2075.

Envisioning early childhood education approximately fifty years into the future requires consideration of the scientific, technological, and societal developments that are likely to shape this period. Based on current advances in biotechnology, artificial intelligence, nanotechnology, and medicine, it is possible to anticipate a range of developmental scenarios characterised by an increasing integration of humans with digital and computational systems (Holmes et al., 2023; Chiu et al., 2023; Tapalova and Zhiyenbayeva, 2022).

Research and development initiatives aimed at establishing direct communication between the human brain and computers, particularly through neurotechnological interfaces, already exist. In the future, such technologies may enable faster acquisition of knowledge and skills, enhancement of cognitive processes, and new forms of human–technology interaction. Within this context, advanced bionic and digital assistive technologies, together with increasingly sophisticated collaboration between humans and artificial intelligence systems in learning and decision-making processes, are expected to play a growing role (Lebedev and Nicolelis, 2017; Chaudhary et al., 2016; Nicolelis, 2022).

Advances in neurotechnology may further enhance memory, attention, and creativity, facilitate the control of technical systems through neural activity, and enable novel forms of non-verbal communication. These developments raise important questions regarding the technological augmentation of human cognitive, conative, and creative capacities, carrying significant pedagogical, societal, and ethical implications (Lebedev and Nicolelis, 2017; Nicolelis, 2022).

Progress in regenerative medicine and neural implants may also lead to more effective treatments for severe diseases and injuries, including neurodegenerative disorders, spinal cord injuries, and sensory impairments. Future innovations are expected to promote increasingly sophisticated functional integration between biological and artificial systems, whereby bionic limbs and sensory prostheses will not merely compensate for lost functions but may also enhance existing human capabilities.

Such developments inevitably raise important ethical concerns, particularly regarding the boundaries between therapeutic applications of technology and its use for enhancing the abilities of healthy individuals (Porayska-Pomsta et al., 2023). In this context, it is reasonable to envisage a hybrid future in which biological and technological dimensions of human development become progressively intertwined, presenting new challenges for educational systems, including early childhood education.

The aim of this paper is to develop a conceptual framework for exploring possible developmental trajectories of early childhood education toward approximately 2075 by integrating insights from pedagogy, neuroscience, artificial intelligence, and contemporary educational technologies. Rather than attempting to predict the future, the paper adopts a foresight approach to stimulate theoretical discussion on potential transformations in learning environments, children's developmental opportunities, and the evolving role of early childhood educators.

Methodology

This study is based on a conceptual foresight research approach, which is widely employed in contemporary research to explore plausible long-term developmental scenarios under conditions of considerable social and technological uncertainty (Organisation for Economic Co-operation and Development [OECD], 2025; Rasa, 2025). Specifically, the study adopts a multi-perspective conceptual approach based on foresight methodology, comprising the following components:

1. Analysis of relevant theoretical literature and international strategic documents addressing early childhood education, the digital transformation of education, and holistic child development;
2. Horizon scanning to identify major technological and societal trends, including artificial intelligence, sensor technologies, augmented and virtual reality (AR/VR), and neurobiological approaches to learning;

3. Synthesis of the findings into a conceptual scenario describing the kindergarten of the future. The literature was analysed using qualitative thematic analysis, through which thematic domains directly related to the study objectives were identified. These included personalised learning, the relationship between movement and cognitive processes, digitally mediated feedback, the hybrid professional role of early childhood educators, and the ethical implications of technology use in work with children.

Particular attention was given to publications addressing artificial intelligence in education, neuroscience, personalised learning, educational technologies, and international foresight studies.

The aim of this study is to conceptually explore possible developmental trajectories of early childhood education toward the year 2075, drawing upon contemporary scientific, pedagogical, and technological knowledge, with particular emphasis on the following:

1. promoting children's holistic development through the integration of physical (motor) and cognitive development;
2. examining the role of advanced digital and neurotechnological systems within educational processes; and
3. exploring the evolving professional role of early childhood educators in technologically enriched and developmentally supportive learning environments.

Limitations of the Study

The limitations of this study stem from its conceptual and foresight-oriented nature. The proposed models and scenarios do not represent empirically validated findings but rather plausible developmental projections grounded in contemporary theoretical, pedagogical, and strategic sources.

Results and Discussion

In the context of the rapid advancement of digital and neurotechnological systems, there is an increasing need for theoretical and conceptual reflection on the long-term developmental trajectories of early childhood education.

Based on current scientific and technological trends, it may be anticipated that educational programmes will become increasingly inclusive, personalised, and globally interconnected over the coming decades (Sahlberg, 2021; Zhao, 2020).

The role of physical education is also expected to become even more prominent as a key contributor to physical development, central nervous system development, health promotion, and emotional well-being (UNESCO, 2020). Educational processes in early childhood settings are likely to be characterised by the widespread use of sensor technologies, hybrid educators, and the comprehensive integration of physical and cognitive development through neurobiological approaches.

Sensor Technologies in Early Childhood Education

The OECD (2021) suggests that advances in digital technologies may make continuous monitoring of children's emotional and cognitive development a common educational practice. Such monitoring could be supported by various types of sensors, including the following:

- wearable devices, such as smart wristbands or smart garments, capable of monitoring heart rate, stress levels, and movement;
- cameras and microphones used to analyse facial expressions, speech, and children's social interactions;
- non-invasive neuro-sensors, such as EEG headbands, for monitoring brain activity during learning and play; and
- hypothetical invasive neurotechnological systems, whose potential application would depend on future scientific advances, ethical standards, and regulatory frameworks.

AI assistants could analyse the collected data, identify developmental difficulties (e.g., problems related to balance or coordination), and recommend appropriate corrective games or exercises to early childhood educators. This approach is consistent with contemporary concepts of learning analytics, which utilise learning-related data to personalise educational processes and support more informed pedagogical decision-making (Romero and Ventura, 2024).

Smart educational equipment could provide immediate visual and auditory feedback, facilitating children's acquisition of motor skills and improving movement self-regulation.

Beyond monitoring motor development, future technologies may also enable the assessment of children's emotional states (e.g., happiness, anxiety, or frustration) and cognitive functions (e.g., attention, memory, and problem-solving) while they are learning or playing. Such information could provide educators with valuable insights into how individual children respond to motor tasks and social situations.

Consequently, learning activities could be personalised by adapting tasks whenever children exhibit disengagement, learning difficulties, or cognitive overload. The principal advantage of such an approach lies in the possibility of designing individually tailored educational programmes while simultaneously providing parents and educators with comprehensive analytical reports on children's development. However, the realisation of these scenarios will depend on the establishment of appropriate ethical standards, regulatory frameworks, and broad societal consensus regarding the acceptable use of technology in early childhood education (OECD, 2021).

Hybrid Educators

Zhao (2020) discusses the possibility that future educational processes will be based on an integrated model in which children simultaneously interact with a human educator and an artificial intelligence-based digital mentor. Within such a model, the human educator retains the central pedagogical role by providing emotional support, facilitating social interaction, and fostering creativity, while artificial intelligence systems contribute analytical insights, developmental monitoring, and personalised learning recommendations (OECD, 2021; UNESCO, 2021).

Contemporary educational foresight analyses suggest that the role of early childhood educators may increasingly assume a hybrid character, combining human expertise with advanced intelligent technologies. As children encounter intelligent digital agents at progressively younger ages, educators are expected to assume greater responsibility for fostering early digital literacy, ensuring safe digital learning environments, and facilitating children's critical understanding of technology through play and inquiry-based activities (Kuusi and Heinonen, 2022).

Advanced artificial intelligence systems may enable continuous monitoring of children's developmental readiness, interests, and individual learning pace, thereby supporting more precise and developmentally appropriate pedagogical interventions (Rahimi and Oh, 2024). Although such technologies offer considerable opportunities for improving educational practice, research consistently indicates that they cannot replace fundamental human competences such as empathy, interpersonal communication, and social sensitivity, all of which remain indispensable when working with preschool children (Rezaei et al., 2023).

Such a concept of the hybrid educator presupposes the continuous professional development of future early childhood educators (Marinšek and Kovač, 2021), the integration of systematic learning analytics, and the processing of data generated by

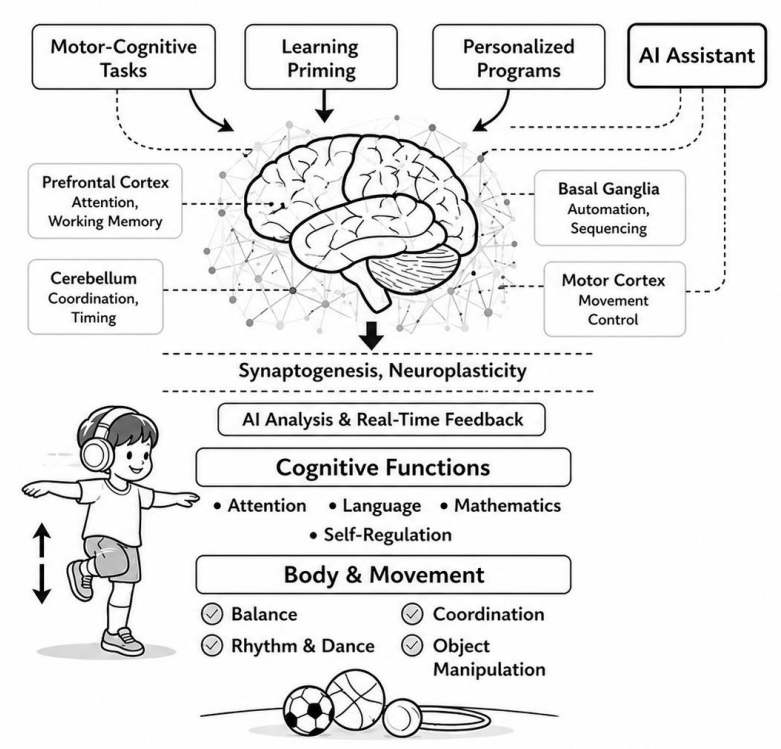
artificial intelligence systems, thereby enabling the development of more precise developmental plans and the adaptation of the pedagogical environment to children's individual needs (Allil, 2024; Romero and Ventura, 2024).
At the same time, research confirms that warmth, stable interpersonal relationships, and non-verbal communication remain fundamental determinants of child development between the ages of three and six and cannot be replicated by technological means (Costello et al., 2020).

Integrating Physical and Cognitive Development Through Neurobiological Approaches
Based on contemporary findings in neuroscience and developmental pedagogy, it can be assumed that, in the coming decades, the integration of physical and cognitive development may become one of the fundamental characteristics of early childhood education and care. This assumption is supported by empirical evidence already demonstrating the effectiveness of integrated physical and cognitive learning in preschool settings (Blažević and Žnidarec Čučković, 2021).
Drawing on contemporary findings in neuroscience and developmental pedagogy, it can be assumed that the integration of physical and cognitive development will become one of the defining characteristics of early childhood education over the coming decades. Physical activity (Figure 1) in early childhood not only promotes motor development but also stimulates the central nervous system, enhances attention and memory, and strengthens the self-regulatory capacities of cognitive control systems (Diamond, 2015; UNESCO, 2020). These findings suggest that movement and cognition are closely interconnected and that diverse forms of physical activity-including running, jumping, balancing, and learning new motor skills-can activate neural networks involved in attention, planning, and memory (Diamond, 2015).
Brain neuroplasticity refers to the brain's capacity to reorganise its neural connections, meaning that motor learning continuously modifies both its structure and function. Balance activities, dance, and ball games have been associated with the development of neural networks that support executive functions, attention, and learning processes, with positive effects that may also transfer to achievement across other educational domains. Although neuroplasticity occurs throughout the lifespan, it is particularly pronounced during childhood, when the brain undergoes rapid development and adapts intensively to diverse experiences and environmental stimuli.

When a child learns a new motor skill, such as catching a ball, specific neural networks are activated. These networks contribute not only to the development of motor control but also to the maturation of cognitive systems that underpin higher-order cognitive functioning. In this sense, physical movement and cognitive development are inseparable processes that evolve simultaneously through experience. Because children demonstrate diverse developmental profiles, the individualisation of motor activities may become a vital component of personalised learning.

Figure 1

Integration of Movement, Brain Function, and AI-Supported Learning in Early Childhood Education



One plausible developmental scenario envisages early childhood education settings equipped with dedicated cognitive-motor training environments, where physical education is systematically employed to provide neurobiological stimulation of the neural networks underlying attention, executive functions, and emotional regulation.

Curricula may incorporate structured protocols of motor activities—including coordination, balance, and precision exercises—designed to prime learning by optimising children's neurobiological readiness for subsequent cognitive tasks (Stodden et al., 2008; UNESCO, 2021).

Such programmes could be specifically designed to strengthen neural networks associated with attention, executive functions, and emotional regulation. For example, brief motor activities performed immediately before cognitively demanding tasks may serve as a form of neurobiological priming that enhances learning readiness (Stodden et al., 2008). To support these processes, augmented reality (AR) and virtual reality (VR) technologies may be used to simulate activities such as catching virtual objects, maintaining balance within immersive digital environments, or synchronising movements with virtual avatars.

Forms of Physical Education

Based on the developmental trends analysed in this study, it may be assumed that the fundamental organisational forms of physical education in the future will remain broadly comparable to those of today—including free play, structured activities, outdoor play and field trips, creative and social games, and micro-blocks of activity. However, their content, organisation, and pedagogical functions are likely to be substantially transformed through the integration of artificial intelligence, sensor technologies, and augmented reality (Madanipour and Cohrssen, 2021; UNESCO, 2021).

Free play is unlikely to consist solely of spontaneous movement. Instead, it may be enriched through interactive play environments, digital content, and multisensory stimuli that simultaneously promote children's motor, cognitive, social, and creative development. For example, interactive floors equipped with pressure sensors and projection systems could generate dynamic motor tasks that enhance coordination, balance, and spatial orientation through continuously changing visual scenarios.

Structured activities may be organised as short, intensive learning units integrating motor learning, neurobiological stimulation, and personalised digital technologies. Such activities could include brief activity cycles (5–10 minutes), neurofeedback systems that automatically adjust task difficulty, complex motor tasks designed to support holistic child development, and combinations of natural and digital environments through augmented reality (AR) technologies (Stodden et al., 2008; Edwards et al., 2012; OECD, 2021; UNESCO, 2021).

Within this context, children might use nano-tactile panels or holographic manipulatives designed to further stimulate the development of fine motor skills and movement precision.

Outdoor activities are likely to retain a central place within the curriculum while being enriched by augmented reality applications that support exploration, movement, and learning. The objective of this approach is not to replace nature with technology but to integrate the two in a complementary manner. For example, children could follow virtual animal tracks, explore plant and animal life through context-sensitive digital information, or solve integrated motor–cognitive tasks embedded within natural environments, thereby simultaneously promoting motor competence, environmental awareness, and digital literacy (OECD, 2021; UNESCO, 2021).

Similarly, virtual reality may provide opportunities for experiential learning within simulated environments, allowing children to explore natural phenomena or distant locations through collaborative motor–cognitive activities, while artificial intelligence systems dynamically adjust task complexity according to each child's individual abilities.

Micro-blocks of activity may consist of brief motor, cognitive, or emotional self-regulation activities incorporated between regular daily routines to restore attention and promote self-regulation (Madanipour and Cohrssen, 2021). Based on children's physiological and cognitive indicators, artificial intelligence systems could recommend personalised activities, such as short motor tasks, breathing exercises, or simple problem-solving challenges, tailored to each child's current condition and developmental needs. Such personalisation is consistent with the principles of learning analytics, which support the adaptation of educational content and activities to children's individual developmental characteristics (Romero and Ventura, 2024).

Taken together, these forms of physical education point toward a possible developmental trajectory in which physical activity is no longer viewed solely as a means of developing motor competence but rather as an integrated pedagogical framework for the simultaneous development of children's motor, cognitive, emotional, and social competences.

Conclusion

Based on the conceptual analysis and the developmental scenarios explored in this study, it can be concluded that early childhood education over the coming decades

is likely to be characterised by a deeper integration of physical, cognitive, and emotional development, supported by increasingly sophisticated digital and sensor technologies. However, the findings do not suggest the replacement of educational relationships by technology; rather, they point toward their transformation within technologically enriched learning environments.

The foresight analysis further suggests that the role of the early childhood educator will remain central, although qualitatively transformed. The educator of the future is likely to become an interpreter of educational data, a designer of meaningful learning experiences, and a guardian of humanistic values within technology-mediated educational environments. At the same time, physical education and movement are expected to retain their vital role in child development while increasingly serving as powerful means of neurobiological and cognitive stimulation.

The principal contribution of this study lies in the development of an integrated conceptual framework that brings together pedagogy, neuroscience, artificial intelligence, and physical education to explore plausible developmental trajectories of early childhood education toward the year 2075. As such, the proposed framework could serve as a theoretical foundation for future empirical investigations and for the development of innovative models of early childhood education.

Author Contribution Statement

Conceptualization and methodology: G. Š.; data collection and analysis: J. M.; writing – original draft preparation: G. Š. and J. M.; writing – review and editing: G. Š. and J. M. Both authors have read and agreed to the published version of the manuscript.

Data Availability Statement

The article is based on archival and other non-digitalized sources, which are listed in the reference list.

Declaration on the Use of Generative AI Tools

No generative AI tools were used in the preparation of this manuscript to generate text, data, code, analysis, interpretations, or visual content. All content within this manuscript is the result of the authors' own original scientific and professional work.

Informed Consent Statement

All research participants were adequately informed about the purpose of the study prior to their participation and provided their informed consent to participate.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this manuscript.

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