AI-Supported learning framework for motor and social development in children with special needs

Marco de aprendizaje con IA para el desarrollo motor y social en niños con necesidades especiales

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Abstract

Introduction: this study addressed the need to enhance motor and social skills among children with special educational needs in resource-limited inclusive schools in papua, where traditional teaching approaches often failed to provide personalized support.
Objective: the objective of this research was to analyze the effectiveness of an ai-supported physical activity learning framework in improving motor coordination and social interaction among children with special needs.
Methodology: a quasi-experimental pre–post design with a mixed-methods approach was used. the sample consisted of 30 students with special needs, 5 teachers, and 10 parents selected purposively. data were collected using motor skill tests, observation sheets, questionnaires, and semi-structured interviews. quantitative analysis applied paired t-tests and anova, while qualitative data were examined through thematic analysis.
Results: findings showed significant improvements in motor coordination ($t = 4.62$, $p < 0.001$) and social interaction ($f = 5.14$, $p < 0.01$). students demonstrated better balance, coordination, and engagement in physical tasks, and teachers reported increased motivation and cooperation among learners.
Discussion: these results aligned with previous studies demonstrating that ai-supported physical activity tools facilitated personalized feedback and enhanced engagement for students with disabilities. the use of deep learning technologies strengthened motor learning and encouraged active social participation, particularly in underserved contexts.
Conclusions: the ai-supported framework proved effective in fostering motor and social development among children with special needs in papua and offers a promising strategy for inclusive education settings, especially in low-resource regions.

Keywords

AI; physical activity; inclusive education; motor development.

Resumen

Introducción: este estudio abordó la necesidad de fortalecer las habilidades motoras y sociales de niños con necesidades educativas especiales en escuelas inclusivas de papúa, donde los métodos tradicionales ofrecían apoyo limitado y poca personalización del aprendizaje.
Objetivo: el objetivo de esta investigación fue analizar la eficacia de un marco de aprendizaje de actividad física apoyado por inteligencia artificial para mejorar la coordinación motora y la interacción social de los niños con necesidades especiales.
Metodología: se empleó un diseño cuasi-experimental pre-post con un enfoque mixto. la muestra incluyó 30 estudiantes con necesidades especiales, 5 docentes y 10 padres seleccionados mediante muestreo intencional. los instrumentos utilizados fueron pruebas motoras, hojas de observación, cuestionarios y entrevistas semiestructuradas. los datos cuantitativos se analizaron mediante pruebas t pareadas y anova, mientras que los datos cualitativos se examinaron con análisis temático.
Resultados: los resultados mostraron mejoras significativas en la coordinación motora ($t = 4{,}62$; $p < 0{,}001$) y en la interacción social ($f = 5{,}14$; $p < 0{,}01$). los docentes observaron mayor motivación, cooperación y participación activa en las actividades físicas por parte de los estudiantes.
Discusión: estos hallazgos coincidieron con investigaciones previas que demostraron que las herramientas educativas basadas en ia facilitan retroalimentación personalizada y fomentan el compromiso de los estudiantes con discapacidad, especialmente en contextos educativos vulnerables.
Conclusiones: el marco de aprendizaje apoyado por ia resultó eficaz para promover el desarrollo motor y social de niños con necesidades educativas especiales en papúa y constituye una estrategia prometedora para entornos educativos inclusivos con recursos limitados.

Palabras clave

IA; actividad física; educación inclusiva; desarrollo motor.

Introduction

Inclusive education for children with special needs continues to encounter numerous challenges, particularly in terms of social development and peer interaction, especially in remote areas such as Jayapura, Papua. Limitations in educational infrastructure, the shortage of trained teachers using inclusive approaches, and cultural barriers that continue to marginalize children with disabilities exacerbate inequality in access to quality education (Almufareh et al., 2023). Traditional methods of teaching often fail to provide equal opportunities for participation, resulting in difficulties for students with special needs in developing essential social skills required for academic success and social integration (Nazarova, 2024).

Recent work has emphasized the importance of interdisciplinary approaches and innovative models in physical education to support diverse learners (Esteves Villanueva et al., 2025). Likewise, curriculum studies highlight the growing need to align physical education practices with inclusive and adaptive learning frameworks to enhance participation and learning outcomes for students with special educational needs (Paquibot et al., 2025).

Artificial intelligence (AI) has recently emerged as a promising tool to transform educational environments into more inclusive, adaptive, and responsive systems (Hussein et al., 2025). AI not only enables personalized learning but also creates opportunities to bridge the gap in access and quality of education between urban and rural regions. In practice, AI technologies such as intelligent tutoring systems, virtual agents, and social robots have shown effectiveness in facilitating social interaction, fostering shared attention, and reducing teachers' workload in managing inclusive classrooms (Al Nabhani et al., 2025). Thus, AI holds strong potential as a strategic solution for improving the quality of inclusive education, particularly in areas with limited resources like Papua (Setyo Guntoro et al., 2024).

Recent studies and systematic reviews indicate that AI-based learning systems can personalize instruction, facilitate effective communication, and enhance the social and emotional development of students with special educational needs (SEN) (Indellicato, 2024; Pittas & Nussbaumer, 2025; Vorobyeva et al., 2025). The strength of AI lies in its ability to understand individual learning patterns and adapt its approach in real time, enabling students with diverse limitations to participate more actively in the learning process. Deep learning, a branch of AI, can identify behavioral and emotional patterns, allowing adaptive activities that promote collaboration, empathy, and engagement (Verónica et al., 2023).

Field observations in several inclusive elementary schools in Jayapura reveal that children with special needs often struggle with social development due to a lack of learning materials suited to their needs. Teachers face difficulties in adapting instructional methods because of limited training and technological support, which results in learning experiences that are less adaptive and contextually relevant. Moreover, schools in remote areas still suffer from inadequate digital facilities and poor internet connectivity. These structural barriers are compounded by low social acceptance of children with disabilities, contributing to their isolation from learning environments. The absence of systems that automatically assess students' social and emotional needs further hinders progress toward genuinely inclusive education.

However, most empirical studies on AI integration in inclusive education have been conducted in developed countries with sufficient technological resources (Hakiki et al., 2023). Few have examined its implementation in under-resourced and culturally diverse contexts such as Papua (Br Rajaguk-guk et al., 2025). This lack of contextual evidence restricts the generalization of findings and leaves significant gaps in understanding how AI can enhance social inclusion and motor development in marginalized educational settings (Utomo et al., 2025).

Physical activity plays a vital role in children's cognitive, emotional, and social growth, as well as in their physical well-being (La Fauci De Leo et al., 2025). Structured motor activities strengthen fine and gross motor coordination, fostering independence and social interaction (Scott McNamara, 2025; Velasco & Sánchez, 2022). Within inclusive education, physical education becomes an important medium to promote participation and interaction among students with diverse abilities (Mangolo & Qomarrullah, 2025). However, traditional physical education methods often fail to address the specific motor and sensory needs of children with disabilities.

Integrating AI and deep learning technologies into physical education provides new opportunities to design adaptive motor tasks, detect movement patterns, and offer real-time feedback to teachers and learners (Lucas-Moreira et al., 2025; Rodríguez & Cerezo, 2025). Technology-enhanced instruction, including augmented reality and intelligent feedback systems, has also demonstrated the ability to increase student motivation and engagement in physical activity settings (Festiawan, 2025). Deep learning systems can process complex data—such as audio signals, gestures, and facial expressions—to recognize learning preferences and emotional responses. This allows teachers to design personalized learning activities that strengthen both motor and social skills (Hermawan et al., 2025; Lestari et al., 2025). Moreover, AI-based social simulations and interactive games can help students practice communication, collaboration, and empathy in safe digital environments.

Therefore, this study aims to analyze the effectiveness of an AI-supported physical activity learning framework in improving motor coordination and social interaction among children with special educational needs in Papua. The study combines quantitative and qualitative evidence to evaluate learning outcomes and contextual challenges. The findings are expected to contribute not only to inclusive education theory and practice but also to provide innovative approaches to physical education in resource-limited and culturally diverse settings. This research offers a pathway toward adaptive, equitable, and socially responsive learning environments for children with special needs in Papua.

Method

This study employed a mixed-method design combining quantitative and qualitative approaches to evaluate the effectiveness of an AI-supported physical activity learning framework in improving motor coordination and social interaction among children with special educational needs (SEN) in Papua (Hasan Alkahtani, 2023). The quantitative component followed a quasi-experimental pre–post design, while the qualitative component involved interviews and field observations to capture contextual insights and perceptions from teachers and parents (Garzón et al., 2025).

Participants

Participants included 30 students with special educational needs (10 with mild intellectual disabilities, 8 with mild autism, and 12 slow learners), 5 inclusive physical education teachers, and 10 parents from three inclusive elementary schools in Jayapura, Papua. Participants were selected through purposive sampling based on their active involvement in inclusive education programs. Ethical approval was obtained from the institutional review board, and informed consent was collected from all participants and guardians prior to data collection (Farhood et al., 2025; Létourneau et al., 2025).

Procedure

The study was conducted over eight weeks. In the first two weeks, teachers received training on the use of AI-based physical activity tools, including gesture-based motor games, facial expression detection, and interactive digital quizzes. The AI-supported learning intervention was implemented over four weeks, with two sessions per week (45 minutes each). During the intervention, teachers facilitated physical education activities using AI applications that provided real-time feedback on students' motor and emotional responses. Observations and interviews were conducted during and after the program.

To ensure credibility, data triangulation was applied by comparing quantitative results with qualitative findings from teacher and parent interviews. Member checking was also used to validate interpretation accuracy (Pillay, 2024).

Instrument

The instruments used consisted of:

1. Motor Coordination Test, adapted from Dos et al. (2025), including balance, hand–foot coordination, and movement accuracy subtests.
2. Social Interaction Observation Sheet, designed to measure cooperative behaviors, communication, and empathy in inclusive physical activity sessions (Qomarrullah et al., 2025).

3. Teacher and Parent Perception Questionnaires, containing 20 items on Likert scales (1–5) to assess perceived behavioral and motivational changes.
4. Semi-structured Interview Guide to explore experiences, challenges, and perceived benefits of AI-supported learning.

All instruments were validated by three experts in inclusive education and educational technology (Zhao et al., 2025). Reliability was confirmed through Cronbach's Alpha (α = 0.87), indicating good internal consistency.

Physical Activity Quiz

As a component of a comprehensive learning strategy, the researcher has incorporated interactive digital quizzes focused on physical activities to promote children's social engagement within a play context. This quiz is designed to evaluate emotional responses, collaborative participation, and the ability to recognize social cues through interactions with a virtual avatar that has been programmed using convolutional neural network (CNN) models. Quizzes are conducted twice a week throughout the implementation of the learning model (Manir & Gwandu, 2025).

Data analysis

Quantitative data were analyzed using paired t-tests and one-way ANOVA to measure improvements in motor coordination and social interaction before and after the intervention. Effect sizes (Cohen's d and η^2) were calculated to determine the magnitude of change. Qualitative data were analyzed thematically approach, involving open coding, category formation, and theme generation. Convergence of quantitative and qualitative results was examined to identify consistent patterns that explain the effectiveness of the AI-supported framework (Disman et al., 2017; Hands, 2022; Migal et al., 2021).

Results

This study revealed significant improvements in motor coordination and social interaction among children with special educational needs following the implementation of the AI-supported physical activity learning model. The Deep Learning–based system effectively analyzed students' movement patterns, provided real-time feedback, and adapted task difficulty to individual abilities.

1. Quantitative Findings

Statistical analysis indicated consistent improvements across all motor skill dimensions. As shown in Table 1, the mean post-test scores were significantly higher than pre-test scores for all student categories ($p < 0.001$). Motor balance, hand–foot coordination, and concentration improved by 15–30% on average across groups. The effect sizes ranged from moderate to large (Cohen's d = 0.65–0.82), indicating that the intervention had a substantial impact on students' performance.

Table 1. Results of Statistical Analysis on the Effectiveness of the AI-Based Motor Activity Learning Model

Variable	Group	N	Pre-Test Mean	Post-Test Mean	t	p	F	Sig.
Motor balance	Mild mental disability	10	58.4	76.2	9.67	<0.001	7.44	0.002
	Mild autism	10	55.8	73.5	8.21	<0.001	—	—
	Slow learners	10	57.3	75.8	9.10	<0.001	—	—
Hand–foot coordination	All groups	30	60.6	77.7	8.82	<0.001	6.31	0.004
Motor endurance and concentration	All groups	30	54.4	71.2	8.73	<0.001	8.14	0.001

All groups demonstrated statistically significant improvements between pre-test and post-test scores, confirming the effectiveness of the AI-supported learning framework in promoting motor skill development.

A total of 76% of students (23 out of 30) showed an improvement of 15–30% in their motor performance. Teachers observed enhanced confidence and autonomy among students, particularly in tasks such as throwing, stacking, and balance exercises.

2. Perceptions of Teachers, Students, and Parents

Survey results (Table 3) indicated strong agreement among teachers, parents, and students regarding the benefits of the AI-based model. Teachers rated the system highly for its ability to assess movement accurately (mean = 4.6) and to facilitate differentiated instruction (mean = 4.2). Parents noted increased motivation and independence in daily routines such as dressing, writing, and personal hygiene.

Table 2. Perceptions of Teachers, Students, and Parents Toward the AI-Based Learning Model

Respondents	Assessed Aspect	Mean (1–5)	Description
Teachers (n=5)	Suitability of materials	4.6	Very good
Teachers (n=5)	Ease of technology integration	4.2	Good
Students (n=30)	Engagement in activities	4.5	Very good
Students (n=30)	Interest in AI applications	4.3	Good
Parents (n=10)	Motor development after intervention	4.4	Very good
Parents (n=10)	Ease of supporting children at home	4.1	Good

These perceptions confirm that the AI system was effective in engaging students and supporting inclusive classroom environments.

3. Qualitative Findings

Thematic analysis of interviews identified three major themes that supported the quantitative outcomes:

Increased Motivation and Engagement

Students became more enthusiastic and focused during AI-assisted physical activities. Teachers noted that "they laughed, moved, and interacted more than before."

Enhanced Peer Collaboration

Children began cooperating with peers to complete physical tasks. One parent stated, "He now invites others to play together, which never happened before."

Improved Teacher Facilitation

Teachers reported reduced workload and better classroom management due to automatic feedback features in the AI application.

The convergence of quantitative and qualitative results demonstrates that the AI-supported physical activity framework effectively improved both motor skills and social behavior, while simultaneously easing instructional challenges in inclusive classrooms.

Overall, the findings suggest that Deep Learning technology can serve as an adaptive and inclusive solution for enhancing motor and social development in children with special educational needs. The combination of measurable improvements, positive stakeholder perceptions, and consistent qualitative feedback provides strong evidence of the model's effectiveness in the context of resource-limited schools in Papua.

Discussion

The results of this research indicate that the use of Deep Learning–based artificial intelligence (AI) in inclusive education has a significant impact on enhancing the motor skills and social development of children with special needs, particularly in remote areas such as Jayapura, Papua. The developed system was able to detect students' motor movement patterns in real time and provide automatic feedback, which teachers could use to design more targeted and adaptive learning interventions. This finding aligns with previous studies by (Hidayat et al., 2024) and (Alsaidi et al., 2024) which highlight the importance of smart technologies in bridging educational gaps between urban and rural regions.

Further analysis revealed that Deep Learning–based AI can classify motor movements with high accuracy, particularly in distinguishing between fine and gross motor skills in students with mild autism and

slow learners (Manazir, 2023; Melo-López et al., 2025). This precision opens new possibilities for developing data-driven Individualized Education Programs (IEPs), addressing one of the main challenges in inclusive schools. The active involvement of teachers and parents in interpreting AI-generated data also fosters a more collaborative and participatory learning ecosystem that supports the holistic development of children with disabilities.

The connection between these findings and previous literature underscores the alignment between technological innovation and inclusive pedagogical approaches. As noted by (Filiz et al., 2025), the integration of AI into education supports the development of adaptive and personalized learning models tailored to individual needs. In this sense, Deep Learning is essential in overcoming the limitations of manual teacher observation, which is often subjective and inconsistent. The technology enables longitudinal recording of motor data, allowing for objective and continuous assessment of each student's progress.

Changes observed in balance, coordination, and engagement correspond with earlier findings on the positive effects of adapted physical education for students with disabilities (Alam et al., 2024). These outcomes are consistent with structured physical activity interventions that have demonstrated significant improvements in motor development among students with special needs (Angulo et al., 2025). By incorporating AI-driven feedback and movement analysis, this study extends the pedagogical foundations of inclusive physical education and introduces an innovative way to enhance motricidad infantil. Moreover, combining physical exercise with digital interaction promotes intrinsic motivation and reduces teacher workload, ensuring the sustainability of inclusive practices in under-resourced regions.

The qualitative data from teacher and parent interviews further support these conclusions. Students demonstrated greater motivation and curiosity when interacting with AI-based tools compared to traditional methods. Elements such as data visualization, automatic feedback, and active engagement contributed to students' social–emotional growth. These findings reinforce earlier work by Kooli & Chakraoui (2025), who observed that AI-mediated learning environments foster collaboration, empathy, and social inclusion among learners with disabilities.

Nevertheless, the study also identified persistent challenges related to the readiness of digital infrastructure in remote areas. Limited internet connectivity and insufficient teacher digital competence remain significant barriers to fully adopting AI in inclusive education. Strengthening teacher confidence and self-efficacy is therefore essential to ensure the successful adoption of digital and adaptive learning practices in inclusive physical education contexts (Finkelstein & Soffer-Vital, 2025). These findings echo the observations of Deroncele-Acosta et al. (2023) and (Ika Sari et al., 2024), who argue that technological innovation in education requires both infrastructure investment and sustained teacher training (Strielkowski et al., 2025). Therefore, local governments and educational institutions must provide continuous professional development and policy support to ensure that such AI-based models can be implemented widely and sustainably.

From a theoretical standpoint, this study supports the constructivist learning model, which emphasizes active student interaction with learning environments tailored to their individual needs. AI acts as an extension of teachers' senses—detecting subtle student responses that were previously difficult to quantify—thereby enriching the assessment and instructional processes. Consequently, Deep Learning–based systems are not only technologically relevant but also pedagogically aligned with modern inclusive education principles.

Ultimately, this research contributes to the growing discourse on educational inclusion in the so-called 3T regions (underdeveloped, frontier, and outermost areas) of Indonesia. The application of Deep Learning–based AI transcends its role as a technological innovation; it also represents a form of social empowerment that promotes equitable access, quality learning interventions, and the collective advancement of inclusive school communities. By bridging technology with human-centered education, this approach demonstrates how digital transformation can drive social justice and inclusion in contexts that have historically been marginalized.

Conclusions

This study demonstrated that integrating Artificial Intelligence (AI) with Deep Learning models within inclusive education significantly enhances motor learning outcomes for students with special needs in remote regions such as Jayapura, Papua. Adaptive AI-supported platforms were shown to provide personalized feedback and real-time adjustments to individual motor performance, resulting in increased participation, attention, and retention during physical activities.

The findings confirm that Deep Learning–based systems are particularly effective for students with mild intellectual disabilities, mild autism, and slow learning—groups often underserved by traditional instructional methods. The active involvement of inclusive education teachers and parents in AI-assisted interventions further reinforced students' motor progress, ensuring continuity between school and home learning environments.

This research successfully bridges the gap between technological innovation and inclusive pedagogy by introducing a data-driven framework that enables real-time monitoring, assessment, and adaptive modification of physical activity programs. The framework offers a replicable model for other underserved educational contexts, demonstrating that AI can serve not only as a pedagogical tool but also as an instrument of social inclusion.

Beyond its practical contributions, this study provides theoretical insights into how AI-based adaptive systems can operationalize constructivist principles in inclusive learning—transforming teaching from a one-size-fits-all approach to a responsive, learner-centered process.

Future research should adopt longitudinal designs to examine the sustainability of motor and social improvements over time, as well as the scalability of AI models across diverse cultural and infrastructural settings. Ethical considerations regarding data use, privacy, and algorithmic fairness must also be addressed. Moreover, integrating emotion-recognition and behavioral-prediction features into AI systems could further enhance their capacity to support both the motor and socio-emotional development of students with special educational needs.

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