NIKA: A HYBRID PLAY-BASED TECHNOLOGICAL EXPERIENCE FOR ENHANCING EXECUTIVE FUNCTIONS AND EMOTIONAL REGULATION IN CHILDREN WITH AUTISM SPECTRUM DISORDER

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Abstract

Executive functions play a crucial role in children's cognitive, emotional, and social development; however, they are frequently impaired in individuals with Autism Spectrum Disorder (ASD), significantly affecting behavioral regulation, cognitive flexibility, and school participation. This research proposes an innovative and inclusive approach to supporting the development of executive functions in children aged 6 to 10 through NIKA, a hybrid play-based experience integrating interactive digital tools, tangible physical devices, and structured collaboration among therapists, educators, and families. The project adopts a design-based research approach, combining iterative prototyping with stakeholder involvement across educational and therapeutic contexts. NIKA integrates a customizable interactive application—designed to adapt to individual sensory, cognitive, and emotional profiles—with four tangible joystick devices developed according to ergonomic and tactile-sensory design principles. Together, these components support the training of working memory, planning, inhibitory control, cognitive flexibility, and emotional awareness through embodied interaction, narrative engagement, and game-based activities. The experience is structured within a narrative environment guided by the character Nika, who motivates and supports the child through progressive storytelling, feedback, and non-competitive gamification strategies. A dedicated platform for therapists and educators enables progress monitoring, activity configuration, and shared observation, fostering continuity across school, home, and therapeutic settings. Grounded in Human-Centred Design, inclusivity, and co-design principles, NIKA represents an significant contribution to educational technology and special education, offering a scalable hybrid system in which technology, play, and relational engagement converge to support executive functions and emotional regulation.

Keywords: Hybrid Play-Based Learning; Educational Technology; Inclusive Design; Autism Spectrum Disorder (ASD); Executive Functions; Human-Centred Design.

1 INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterised by persistent difficulties in social communication and interaction, restricted and repetitive patterns of behaviour, and atypical sensory processing. Beyond these core diagnostic features, a substantial body of research has consistently documented impairments in executive functions (EF)—including working memory, inhibitory control, planning and organisation, self-monitoring, and cognitive flexibility—which play a crucial role in learning, autonomy, and social participation [1], [2], [7]–[9]. In educational contexts, executive dysfunction in children with ASD frequently manifests as difficulties in managing transitions, coping with uncertainty and change, sustaining attention, and regulating emotional responses. These challenges can significantly affect classroom participation, adaptive functioning, and overall wellbeing, particularly in inclusive school environments [3], [7], [8].

In response to these needs, research in educational technologies and special education has increasingly explored play-based and "serious play" approaches as effective means to support executive functioning and emotional regulation. Such approaches are especially promising when they are motivating, embodied, and adaptable to heterogeneous cognitive and sensory profiles [4], [5], [10]–[13]. Nevertheless, many existing solutions remain either predominantly screen-based—thus potentially increasing sensory overload and limiting embodied interaction—or confined to specific contexts, such as clinical therapy or home use. This fragmentation often constrains the transfer of acquired skills across environments and weakens continuity among educational, therapeutic, and familial support systems.

This article will be included in the INTED2026 Proceedings (ISBN: 978-84-09-82385-7)
It will be fully citable as soon as it appears in IATED Digital Library (library.iated.org)

The NIKA project addresses these limitations through the development of a hybrid system that integrates (i) a digital interactive application, (ii) tangible physical devices designed to foster embodied and sensorimotor engagement, and (iii) a shared platform supporting collaboration among therapists and educators. Originating from a design-driven research process, the project aims to: support the training of executive functions through playful, narrative-based activities; integrate strategies for emotional awareness and regulation via feedback mechanisms and narrative mediation; promote continuity and coherence across therapeutic, educational, and family contexts; translate inclusive, human-centred, and co-design principles into concrete interface, interaction, and product design requirements.

2 METHODOLOGY

2.1 Research approach

The research adopts a qualitative Design-Based Research (DBR) methodology, integrating theoretical inquiry, iterative design experimentation, and evaluation within ecologically valid educational and therapeutic contexts [6]. DBR is particularly appropriate for addressing complex educational challenges, as it enables the simultaneous development of innovative artefacts and context-sensitive design knowledge grounded in real-world practice rather than laboratory-based abstraction. Within this framework, the design process unfolds through iterative cycles of analysis, design, implementation, and reflection, allowing the continuous refinement of both the artefact and the underlying design assumptions. The methodology supports responsiveness to emergent insights derived from user interaction, stakeholder feedback, and contextual constraints, which are especially relevant when working with heterogeneous populations such as children with Autism Spectrum Disorder.

The DBR process is further structured through Human-Centred Design (HCD) principles, which position users' needs, abilities, and lived experiences at the core of the design activity [6], [14]. Rather than focusing exclusively on the child as an isolated user, the project conceptualises the child as embedded within a broader relational ecosystem that includes therapists, educators, and caregivers. This systemic perspective informs design decisions at both the interaction and infrastructural levels, ensuring coherence between individual experience and collective educational practices.

2.2 Theoretical framework

The methodological approach is grounded in an interdisciplinary theoretical framework that integrates contributions from multiple domains relevant to autism, learning, and design. Specifically, the project draws on:

1 Models of executive functions from developmental neuropsychology, with particular reference to working memory, inhibitory control, planning, monitoring, and cognitive flexibility;

2 Theories of emotional regulation, emphasising the reciprocal relationship between cognitive control and affective processes;

3 Perspectives on embodied cognition, which conceptualise cognitive processes as intrinsically linked to bodily action and sensorimotor experience;

4 Theories of play-based learning and psychomotor approaches, which frame play as a privileged context for learning, motivation, and self-regulation [10]–[13];

5 Principles of inclusive design and educational technology design, addressing accessibility, adaptability, and user diversity [14], [15], [18].

Special attention is devoted to the interdependence between executive functioning and emotional regulation. Empirical research indicates that difficulties in inhibition, flexibility, and planning often manifest as heightened emotional reactivity, stress, and behavioural dysregulation in children with ASD [7]–[9]. Accordingly, the project adopts an integrated perspective in which cognitive and emotional dimensions are treated not as separate training targets, but as mutually influencing processes to be addressed through coherent interaction design.

2.3 User research and requirements definition

User research constituted a foundational phase of the project and informed the translation of theoretical assumptions into operational design requirements. This phase involved a qualitative investigation articulated across multiple complementary activities, including:

1 An analytical review of existing digital, physical, and hybrid tools employed in therapeutic and educational interventions for children with ASD;

2 Observational insights derived from psychomotor practices and educational settings, with attention to interaction patterns, engagement strategies, and critical moments of difficulty or overload;

3 The identification of recurrent needs and constraints related to sensory processing, attentional regulation, motivation, autonomy, and adult mediation.

Findings from this phase highlighted the necessity of balancing stimulation and control, engagement and predictability, autonomy and guided support. On this basis, a set of core design requirements was defined, including sensory adaptability and modulation; multimodal interaction combining visual, auditory, and tactile channels; clear and consistent feedback systems supporting self-monitoring; and mechanisms enabling adult monitoring, personalisation, and mediation.

2.4 Design principles and inclusion criteria

The design of the NIKA system was guided by a set of explicit principles aimed at ensuring inclusivity, accessibility, and adaptability for children with Autism Spectrum Disorder. These principles function as operational bridges between theoretical constructs and concrete design decisions, informing both interface and product development [14], [15], [17].

First, sensory modulation was addressed through the implementation of fine-grained control over visual, auditory, and interaction parameters. Second, predictability and structural coherence were prioritised through consistent interaction patterns and explicit cause–effect relationships. Third, embodied interaction was intentionally integrated through tangible physical joysticks, reflecting an embodied cognition perspective that recognises the role of sensorimotor engagement in supporting executive and emotional regulation [10], [16]. Finally, relational inclusion was established as a central design criterion, embedding interaction within a shared educational infrastructure that supports collaboration among therapists, educators, and families.

3 RESULTS

3.1 System overview

NIKA is conceived as a hybrid educational ecosystem resulting from an iterative design process grounded in Design-Based Research principles. The system integrates a digital interactive application with four tangible physical joystick devices, enabling simultaneous engagement with digital content and embodied action.

The overall structure is organised as a narrative journey across symbolic “islands”, each associated with specific cognitive and emotional challenges related to executive functioning. This structure reflects the design intention to embed executive training within meaningful and coherent experiential contexts, rather than isolated task execution.

The hybrid configuration supports sustained attention and engagement by balancing sensory stimulation and motor involvement, aligning with embodied cognition theories that emphasise the interdependence between action, perception, and cognitive control.

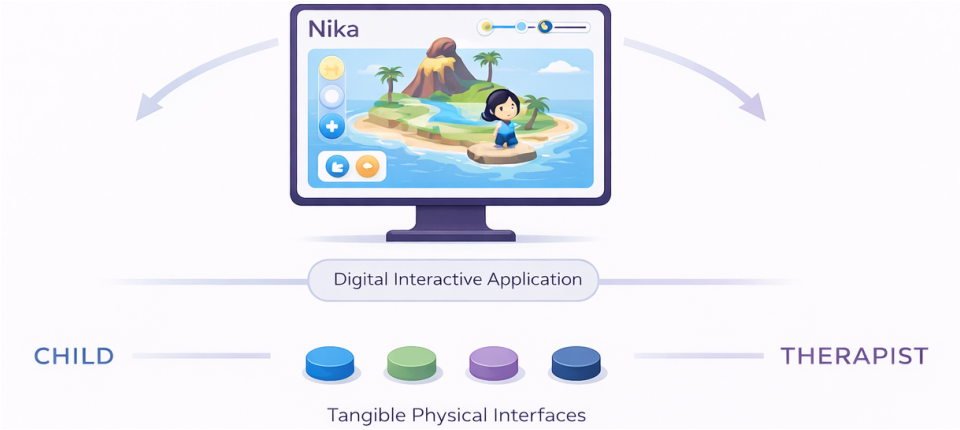

***Figure 1**. Overview of the NIKA hybrid system, designed by Anna Cimminnisi, integrating a digital interactive application and tangible physical interfaces within a shared framework supporting executive functions and emotional regulation across educational and therapeutic contexts.*

3.2 Narrative structure and gamification

Narrative and storytelling constitute a central design component for supporting motivation, emotional involvement, and cognitive continuity. The character Nika functions as a narrative mediator, accompanying the child through progressive stages of the experience and framing challenges within a coherent storyline. Each narrative "island" introduces activities targeting specific executive functions—such as inhibition, working memory, cognitive flexibility, or planning—while maintaining a stable narrative logic. Gamification elements, including levels, rewards, progressive goals, and immediate feedback, are employed to reinforce perseverance and self-efficacy. Importantly, these elements are deliberately designed to avoid competitive dynamics, prioritising intrinsic motivation and emotional safety over performance comparison.

3.3 Tangible interfaces and embodied interaction

The four physical joystick devices represent a core outcome of the embodied design approach. They are differentiated in shape, weight, material, and texture in response to ergonomic and sensory considerations identified during user research [15], [17].

These tangible interfaces support motor coordination, tactile perception, and body awareness, enabling executive processes to be exercised through physical action. Planning, inhibition, and monitoring are activated as children must anticipate movements, regulate impulsive responses, and adapt strategies based on real-time feedback. This embodied interaction reinforces the connection between cognition, emotion, and action, operationalising embodied cognition principles within the design.

3.4 Inclusive and adaptive interface design

The digital interface is designed to ensure accessibility and inclusivity through extensive personalisation of sensory parameters, including colours, sounds, brightness, and interaction pace. This adaptability accommodates a wide range of sensory profiles, addressing both hypersensitivity and hyposensitivity. Design decisions prioritise clarity, reduction of cognitive load, predictable navigation, and consistent feedback mechanisms. These features support usability for neurodiverse users while maintaining engagement and autonomy, translating inclusive and human-centred design principles into concrete interaction solutions.

3.5 Multi-context integration

A dedicated version of the application is designed for therapists and educators, enabling monitoring of progress, activity configuration, and documentation of observations. This functionality supports shared understanding and coordinated intervention across therapeutic, educational, and family contexts.

By facilitating communication and continuity, the system addresses a common limitation of context-specific tools and reinforces the relational dimension of inclusion, positioning NIKA as an infrastructural element within a broader educational ecosystem rather than an isolated intervention.

3.6 Training executive functions through play dynamics

Within NIKA, executive functions are trained through playful dynamics rather than explicit instruction or repetitive drills. Working memory is stimulated through activities requiring the retention and manipulation of information across sequential actions. Inhibitory control is engaged by introducing moments where impulsive responses must be withheld in favour of delayed or alternative actions.

Cognitive flexibility is supported through scenarios that encourage strategy switching, adaptation to new rules, or changes in narrative conditions, while planning skills are developed through tasks requiring anticipation, sequencing, and goal-oriented behaviour. These executive processes are not treated as isolated cognitive targets but are embedded within emotionally meaningful and narratively structured contexts.

3.7 Emotional regulation and narrative mediation

Emotional regulation is supported through a combination of narrative mediation and feedback mechanisms. The character Nika functions as an emotional guide, helping children recognise moments of difficulty, frustration, or success and contextualising them within the learning journey.

Errors are reframed as opportunities for exploration rather than failure, promoting emotional resilience and reducing performance anxiety. Feedback is designed to be informative and supportive rather than evaluative, encouraging self-reflection and emotional awareness. The integration of storytelling, embodied interaction, and adaptive feedback contributes to the development of emotional regulation strategies alongside executive functioning.

4 DISCUSSION

This study set out to explore how a hybrid, design-driven system could support the development of executive functions and emotional regulation in children with Autism Spectrum Disorder through play-based, embodied, and inclusive interaction. The results illustrate how the NIKA system operationalises theoretical constructs from executive function research, embodied cognition, and inclusive design within a coherent educational ecosystem, translating abstract frameworks into concrete interaction and system-level solutions.

First, the hybrid configuration combining digital interaction and tangible physical devices directly addresses limitations identified in prior educational technologies for ASD, which are often either predominantly screen-centred or confined to specific contexts. By integrating embodied interaction through tangible joysticks, NIKA supports executive processes—such as planning, inhibition, and monitoring—via sensorimotor engagement. This design outcome aligns with embodied cognition theories suggesting that cognitive control and emotional regulation are strengthened when learning activities involve bodily action rather than purely abstract interaction [10], [16].

Second, the narrative structure and non-competitive gamification strategies emerge as key mediators of motivation and emotional engagement. Rather than relying on performance-based reinforcement, the system frames challenges within a coherent story, allowing children to attribute meaning to cognitive demands. This narrative mediation appears particularly relevant for emotional regulation, as it reframes difficulty and error as integral components of the learning process, thereby reducing anxiety and supporting emotional resilience.

Third, the results highlight the importance of adaptive and inclusive interface design in addressing sensory heterogeneity. The extensive personalisation of visual and auditory parameters responds directly to the variability of sensory thresholds in children with ASD [7], [14], [15], mitigating the risk of overload while maintaining engagement. This adaptability demonstrates how inclusive design principles can be translated into concrete interface-level decisions that support accessibility without simplifying cognitive challenge.

Importantly, the multi-context integration of NIKA represents a significant contribution to the continuity of educational and therapeutic interventions. By enabling shared monitoring and configuration among therapists, educators, and families, the system moves beyond isolated use scenarios and supports coordinated mediation across environments. This relational dimension reinforces the view of executive function development as a situated and socially supported process rather than an individualised training task.

Finally, the design-driven research approach adopted in this study proves effective in bridging theory and practice. The iterative prototyping of NIKA allowed design decisions to be continuously informed by theoretical insights and user-related constraints [6], [18], [19], generating design knowledge that extends beyond the artefact itself. From this perspective, the project contributes not only a functional system but also a methodological model for the development of inclusive educational technologies addressing complex neurodevelopmental needs.

5 CONCLUSIONS AND FUTURE DEVELOPMENTS

This study presented *NIKA*, a hybrid, play-based educational system designed to support the development of executive functions and emotional regulation in children with Autism Spectrum Disorder. Grounded in a design-driven research approach and informed by human-centred and inclusive design principles, the project addresses the need for educational technologies capable of integrating cognitive, emotional, and embodied dimensions of learning.

By combining digital interaction with tangible physical interfaces and narrative mediation, NIKA contributes a model in which executive function training is embedded within meaningful and emotionally supportive experiences rather than isolated or purely instructional tasks. The system demonstrates how embodied interaction and adaptive interface design can be leveraged to accommodate sensory diversity while sustaining engagement and autonomy in neurodiverse users.

Beyond the individual user experience, the project highlights the importance of multi-context continuity in educational and therapeutic interventions. The integration of a shared platform for therapists, educators, and families supports coordinated mediation and reinforces the view of executive function development as a situated and relational process. In this sense, NIKA functions not only as a learning tool but also as an infrastructural component within a broader educational ecosystem.

From a methodological perspective, the research confirms the suitability of design-based research for addressing complex challenges at the intersection of educational technology, special education, and design [6], [19]. The iterative prototyping process enabled a continuous dialogue between theory and practice, generating design knowledge that extends beyond the specific artefact and may inform the development of future inclusive educational systems.

Future work will focus on empirical validation through longitudinal studies, systematic evaluation of learning outcomes, and the exploration of scalability across diverse educational and therapeutic contexts. These developments will further clarify the potential of hybrid, design-driven approaches to contribute to inclusive and sustainable practices in educational technology and special education.

ACKNOWLEDGEMENTS

The authors wish to thank the professionals, educators, and families who contributed insights during the development of the project, as well as the academic institutions that supported the research.

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