Virtual Reality and Primary School: enhancing motor and socio-emotional skills through Educational Neuroscience

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Abstract
This study investigates the effectiveness of using immersive virtual reality (VR) in physical education and sports programmes in primary schools, with a particular focus on the inclusion of pupils with autism spectrum disorders (ASD). The Educational Neuroscience-based intervention involved 100 students (aged 6–8), who were divided into an experimental and a control group. Standardised quantitative tools (TGMD-2, the Charlop-Atwell Coordination Test, and the SDQ) and qualitative interviews with curriculum and support teachers were employed. The results showed that the experimental group had made significantly greater improvements in locomotor and object control skills, and had experienced a reduction in socio-emotional difficulties and social anxiety. Teachers reported greater student engagement, particularly among those with ASD, due to the predictability and reassuring nature of the virtual scenarios. However, the irreplaceable value of real peer interactions was reiterated, confirming that VR complements, but does not replace, traditional methodologies. In conclusion, immersive VR emerges as an innovative teaching tool, capable of enhancing motor skills, motivation and socio-relational inclusion when incorporated into a pedagogical project that values the balance between technology, physicality and sociality.

Keywords: *Virtual Reality, Educational Neuroscience, Motor Skills, Socio-Emotional Skills, Inclusion, Primary School.*

Introduction

In recent years, inclusive education has experimented with innovative methodologies that integrate advanced technology to support students' cognitive, motor, and emotional development. Educational neuroscience, which combines neuroscience, psychology and pedagogy, has revealed the deep link between learning processes and brain function, emotions and bodily experiences (Immordino-Yang, 2020; Tokuhama-Espinosa, 2021). Research in this field has revealed that learning is never purely cognitive, but rather involves sensory, motor and emotional elements that work together to build stable neural networks and intrinsic motivation in students. According to this approach, the educational environment should be designed as a stimulating, multisensory space that supports brain plasticity and can adapt to children's different learning styles, including those with Autism Spectrum Disorders (ASD). At the same time, immersive virtual reality (VR) has established itself as a particularly

promising educational tool. Unlike other digital technologies, VR enables students to fully immerse themselves in interactive, three-dimensional environments where they can explore, act and learn first-hand (Radianti et al., 2020; Parong & Mayer, 2021). This experiential dimension promotes situated learning because students are active participants in activities that integrate body, emotions and cognition, rather than simply receiving knowledge passively. Furthermore, the ability to create safe and controlled contexts reduces anxiety and frustration, thereby stimulating curiosity and motivation, even among the most vulnerable students. VR lends itself to personalised and inclusive teaching, as it enables tasks, feedback and levels of challenge to be adapted to individual abilities (Sartori et al., 2022; Karami et al., 2023). Several studies in the literature have shown that immersive applications can promote motor development and coordination by providing interactive scenarios in which children can practise their fine and gross motor skills in engaging and repeatable contexts (Pietrabissa et al., 2021; Caggianese et al., 2022). At the same time, VR has been shown to be effective in developing socio-emotional skills, reducing social anxiety, facilitating positive interactions with peers and promoting emotional regulation by simulating cooperative situations (Hamilton et al., 2021; Slater & Sanchez-Vives, 2022). Furthermore, avatars and collaborative scenarios can foster a sense of belonging and encourage inclusive practices, particularly among children with SLDs who typically require structured and predictable environments to develop positive relationships (Bottiroli et al., 2023; Cheng et al., 2024).

Against this backdrop, the present study explores the efficacy of an educational motor and sports programme based on immersive VR, evaluating its impact on the acquisition and enhancement of fine and gross motor skills, as well as the development of socio-emotional competencies, in primary school children. Particular attention is paid to pupils with Autism Spectrum Disorders (ASD), for whom VR can provide a protected and highly customisable environment, capable of reducing barriers related to social anxiety and promoting experiences of inclusion. Thus, the proposed programme is an innovative educational intervention and a significant contribution to an educational model integrating neuroscience, technology, and inclusive practices to promote children's harmonious and comprehensive growth.

1. Aim of the research

This study aims to analyse the extent to which a physical education and sports programme based on immersive virtual reality (VR) and founded on the principles of educational neuroscience can positively impact two key areas of primary school children's development. The first objective is to enhance motor skills, including locomotor skills such as running, jumping, galloping and sliding, as well as object control skills such as grasping, throwing and kicking. Recent neuroscientific evidence highlights the fact that motor activity stimulates brain plasticity and promotes sensorimotor integration, which has direct implications for cognitive development and executive functions (Cespedes & Rueda, 2020; Diamond, 2022). Using immersive VR in motor activities enables the creation of interactive and engaging scenarios in which children can practice repeatedly and safely, thereby improving coordination, balance, and complex motor skills (Pietrabissa et al., 2021; Caggianese et al., 2022; Li et al., 2023). Secondly, the research aims to evaluate the programme's impact on socio-emotional skills, particularly in reducing relational difficulties, increasing peer interactions, and improving emotional regulation. Numerous studies have demonstrated that VR can facilitate the development of empathy, cooperation, and emotional regulation by enabling the simulation of social situations in structured and controllable environments (Hamilton et al., 2021; Slater & Sanchez-Vives, 2022; Cheng et al., 2024). Furthermore, recent applications have shown that VR can reduce levels of social anxiety and promote the inclusion of children with Autism Spectrum Disorders (ASD), offering personalised and predictable experiences that reinforce a sense of security and belonging (Sartori et al., 2022; Bottiroli et al., 2023).

In summary, the objective of this study is twofold: on the one hand, to verify whether and how immersive VR can improve motor skills in school-age children; on the other hand, to investigate its potential in promoting an inclusive environment that strengthens socio-emotional skills, in line with the latest perspectives in Educational Neuroscience and inclusive pedagogy (Tokuhama-Espinosa, 2021; Karami et al., 2023).

1.1 Sample Selection

The study was conducted in a primary school located in Naples and involved a total of 100 students, aged between 6 and 8, from several classes within the same comprehensive school. The sample was divided into two homogeneous groups:

- Control group (50 pupils), who carried out physical activities following a traditional teaching methodology based on structured physical exercises and movement games in the gym or in dedicated spaces.
- Experimental group (50 students), which participated in a physical education and sports programme enriched by the use of immersive Virtual Reality (VR), through interactive environments and scenarios designed to stimulate motor skills and socio-emotional skills.

Within both groups, there were four pupils diagnosed with Autism Spectrum Disorder (ASD), who were regularly integrated into school activities thanks to the support of support teachers. This division allowed for a systematic comparison not only between the two methodological approaches (traditional vs. VR), but also for an assessment of the inclusive impact of the programme on students with special educational needs.

The inclusion criteria adopted were defined to ensure participation by students who could fully benefit from the educational programme and to ensure the homogeneity of the sample. They included:

- Absence of severe motor deficits that would prevent active participation in motor and sports activities. This criterion is fundamental, as VR-supported motor education interventions require a minimum level of motor function to interact effectively with digital stimuli and benefit from training (Li et al., 2023; Caggianese et al., 2022).
- Informed consent from families, which is necessary for participation in research projects that integrate immersive technologies. Recent literature emphasises the importance of involving families as active participants in inclusive educational programmes, particularly when experimenting with innovative tools such as virtual reality (Bottiroli et al., 2023; Cheng et al., 2024).
- Regular attendance at activities, a requirement that ensures the continuity of the educational programme and the reliability of the data collected. Recent studies show that consistent participation is a determining factor in consolidating the benefits of VR, both in terms of motor skills and socio-emotional development, especially in children with Autism Spectrum Disorders (Sartori et al., 2022; Hamilton et al., 2021).
- Integration into an already established inclusive environment, with the presence of curricular and support teachers. International research highlights how the effectiveness of innovative approaches also depends on the relational and professional support offered by adult mentors, who act as mediators between technology, content and students (Karami et al., 2023; Immordino-Yang, 2020).

These criteria not only allowed for the selection of a representative sample of the school population, but also ensured that the immersive VR-based educational programme could be tested in pedagogically and ethically appropriate conditions, promoting inclusion and equal opportunities for participation.

1.2 Tools

To ensure a comprehensive and rigorous assessment, the study was designed using a mixed qualitative-quantitative approach, combining the objective collection of numerical data with the analysis of subjective perceptions and experiences. This methodological choice made it possible to explore the motor and socio-emotional dimensions of children's development in an integrated manner, capturing both measurable progress and observable changes within the inclusive school context.

The quantitative tools used to assess children's motor and socio-emotional development included:

- TGMD-2 (Test of Gross Motor Development, Ulrich, 2000): this is a standardised tool widely used internationally to measure fundamental motor skills in children. The test is divided into two main subscales: *locomotor skills* (such as running, jumping, galloping, sliding) and *object control skills* (grasping, throwing, kicking). The TGMD-2 is highly reliable and sensitive, making it particularly suitable for identifying differences in motor performance even in children with Autism Spectrum Disorders (Kim et al., 2020; Bardid et al., 2021). In addition, several studies have shown that the TGMD-2 can be used in combination with digital tools and immersive technologies to monitor motor progress over time, providing replicable and comparable data (Estevan & Barnett, 2021; Robinson et al., 2022).
- Charlop-Atwell Motor Coordination Test: this tool assesses both gross and fine motor coordination, analysing the level of integration between basic motor skills and voluntary motor control. Its application, combined with the TGMD-2, provides a more comprehensive picture of motor skills, integrating the measurement of fundamental skills with the assessment of more complex functions, such as precision and motor adaptation. This complementarity has proven particularly useful in inclusive educational settings, where children have heterogeneous developmental profiles (Miller et al., 2019; Capio et al., 2022; Westendorp et al., 2023).
- SDQ (Strengths and Difficulties Questionnaire, Goodman, 1997): a widely used international screening questionnaire for assessing socio-emotional skills and behavioural difficulties. It consists of 25 items divided into five scales (emotional problems, conduct problems, hyperactivity/inattention, problems with peers, and prosocial behaviour). The tool is suitable for detecting significant changes in children's social and emotional behaviour, with a particular focus on relational dynamics and the degree of adaptation in the school context. Studies conducted in recent years have confirmed the reliability of the SDQ even in multicultural and inclusive school environments, as well as its effectiveness in monitoring innovative educational programmes (Niclasen et al., 2019; Giannakopoulos et al., 2021; Hoffmann et al., 2023; Zhang et al., 2024).

In terms of quality, semi-structured interviews were conducted with curriculum and support teachers. The interviews aimed to gather teachers' perceptions of the programme's effectiveness, the changes observed in children, and the dynamics of inclusion within the class group. Using a semi-structured methodology ensured a balance between expressive flexibility and the comparability of the collected data, while encouraging the emergence of individual experiences and subjective perspectives that are often not reflected in standardised tools (Mertens, 2020; Nowell et al., 2022).

The interview transcripts were analysed using thematic analysis with the support of NVivo software. This allowed the data to be coded systematically, recurrences to be identified, and information to be organised into interpretative categories. Using NVivo made the analysis process more transparent, traceable and replicable, reducing subjectivity in the interpretation phase and increasing consistency among the various researchers involved (Castleberry & Nolen, 2018; Woods et al., 2020; Bengtsson, 2022).

This mode of analysis has proven particularly useful in inclusive educational contexts where observable processes are strongly influenced by relational, cultural and organisational variables. Using a thematic approach made it possible to identify recurring patterns in teachers' perceptions of engagement, motivation, and peer interaction. It also revealed significant differences related to the context and characteristics of class groups (Black et al., 2021; Ergas, 2022; Chen et al., 2024).

1.3 Activities

The educational intervention took place over a period of six months, involving two weekly meetings, each lasting one hour and thirty minutes. This approach ensured sufficient educational continuity to produce observable changes in motor and socio-emotional skills, while facilitating a systematic comparison between the two planned courses. The intervention comprised two distinct programmes, both with the same duration and schedule, but with different methodologies: a traditional approach based on school physical education and an innovative programme integrating immersive virtual reality (VR). Students in the control group followed a programme based on traditional school physical education methodologies to strengthen basic motor skills and develop social and relational skills through movement. The activities were designed to be gradually progressive, to adapt to the pupils' different starting levels and encourage their inclusive participation. The sessions were divided into several phases:

- Warm-up exercises and dynamic stretching, aimed at preparing the body for physical activity, improving joint mobility and reducing the risk of injury. These exercises also helped to develop body awareness and concentration before more complex activities (Fraser-Thomas et al., 2021).
- Motor courses in the gym, organised with progressive stations of increasing difficulty (jumping through hoops, obstacle courses, balance exercises on low beams), which stimulated agility, general dynamic coordination and motor adaptation skills. These activities allowed pupils to experience gradual challenges, increasing both their physical skills and self-confidence (De Meester et al., 2020).
- Fine and gross coordination activities, carried out with light equipment (hoops, ropes, soft balls), aimed at enhancing precision of movement, eye-hand coordination and motor dexterity. The use of a variety of tools encouraged experiential learning and allowed students to adapt their movements to the task at hand (Lopes et al., 2021).
- Ball games, including passing, dribbling, shooting hoops and kicking towards targets, which not only helped to improve object control skills but also promoted collaboration, communication and respect for shared rules. The playful component made these activities particularly motivating and inclusive (Rosa et al., 2022).
- Cooperative and regulated competitive team games, such as simplified handball or relay races, which stimulated fundamental social skills, including role management, collaboration and the ability to deal with conflict situations constructively (Bailey et al., 2023; Rudd et al., 2024).

The students in the experimental group participated in a motor programme enriched by the use of immersive virtual reality (VR), designed to integrate motor training with interactive, multisensory and highly customisable experiences. The use of VR made it possible to recreate three-dimensional virtual environments that simulated engaging play and sports scenarios, in which children could experiment with locomotor and object control skills in safe, repeatable conditions adapted to their individual skill levels (Li et al., 2023; Caggianese et al., 2022). The main activities included:

- Locomotor training in VR: virtual courses that required running, jumping, galloping or sliding to overcome obstacles or reach set goals. These activities stimulated overall dynamic coordination, balance and endurance, with the advantage of providing immediate visual and auditory feedback useful for correcting movements in real time (Pietrabissa et al., 2021; Hamilton et al., 2021).
- VR object control: interactive exercises simulating throwing, catching or kicking virtual objects, with progressive difficulty levels calibrated to individual performance. This promoted the development of hand-eye coordination, precision and motor anticipation, which are fundamental aspects for transferring skills to real-life contexts (Estevan & Barnett, 2021; Robinson et al., 2022).
- Socio-emotional activities in VR: cooperative simulations, such as challenges in pairs or small virtual groups, designed to stimulate collaboration, empathy and emotional regulation. The use of VR in this area has made it possible to create controlled social scenarios, reducing the anxiety-inducing factors typical of face-to-face interactions and offering students with Autism Spectrum Disorders (ASD) the opportunity to experience relational dynamics in predictable contexts (Sartori et al., 2022; Slater & Sanchez-Vives, 2022; Bottiroli et al., 2023).
- Immersive mini-games: playful activities, such as virtual treasure hunts or cooperative missions, which required a combination of motor and communication skills to achieve common goals. These experiences reinforced intrinsic motivation, promoting a sense of self-efficacy and active involvement (Cheng et al., 2024; Karami et al., 2023).

One distinctive feature of the course was the use of immediate feedback. Through visual, auditory and tactile signals, students could monitor their progress and correct any errors, enabling them to experience continuous, reinforcing learning (Hamilton et al., 2021; Li et al., 2023). The immersive nature of VR stimulated motivation, sustained attention, and enjoyment of learning while alleviating performance anxiety by enabling practice in safe, non-judgmental, and customisable virtual environments (Radianti et al., 2020; Caggianese et al., 2022). Finally, curricular and support teachers and motor skills experts played a central role, acting as mediators between virtual experiences and the specific needs of students to ensure the full inclusion of the class group. Recent literature confirms that the presence of educational role models is crucial to realising the potential of VR and transforming the digital experience into an opportunity for shared motor and socio-emotional growth (Immordino-Yang, 2020; Ergas, 2022).

2. Data Analysis

2.1 Quantitative data analysis

The analysis of quantitative data highlighted significant differences between the control group and the experimental group, both in motor skills and socio-emotional skills. With regard to motor skills, the TGMD-2 results showed an average improvement of +15% in the control group, while in the experimental group the increase was +40%, with a positive difference of +25% in favour of VR. In particular:

- Locomotor skills: +12% in the control group vs +37% in the experimental group.
- Object control: +18% in the control group vs +43% in the experimental group.

These data confirm that VR promotes the development of general dynamic coordination and motor precision to a greater extent than traditional methods, thanks to unlimited repetition, immediate feedback and task customisation (Li et al., 2023; Robinson et al., 2022). Similarly, the Charlop-Atwell test revealed an average improvement of 14% in fine and gross motor skills in the control group, compared to 36% in the experimental group. Immersive activities involving virtual objects in particular enhanced hand-eye coordination by +22%,

compared to the traditional approach, and improved the ability to adapt to new and complex tasks (Capio et al., 2022; Westendorp et al., 2023).

On a socio-emotional level, data collected via the SDQ indicated that:

- Problems with peers decreased by -8% in the control group, while in the experimental group the reduction was -25%.
- Social anxiety decreased by -6% in the control group, compared to a decrease of -21% in the experimental group.
- Prosocial behaviour increased by +12% in the control group, compared to an increase of +31% in the experimental group.

These results suggest that the opportunity to interact in controlled and safe virtual environments promoted collaboration, empathy, and emotional regulation to a greater extent (Slater & Sanchez-Vives, 2022; Cheng et al., 2024).
A particularly significant aspect concerns pupils with Autism Spectrum Disorder (ASD) in both groups.

- In the control group, pupils with ASD showed an average improvement of +10% in motor tests and +7% in socio-emotional dimensions, with limited progress mainly in fine coordination and persistent difficulties in peer relationships.
- In the experimental group, however, the same students recorded an average increase of +30% in motor skills (with a +20% gain compared to the pre-test in the TGMD-2) and +22% in socio-emotional scales, particularly in the reduction of anxiety and increase in prosocial behaviours.

These results confirm the most recent evidence that virtual reality (VR) is a highly favourable learning environment for students with special educational needs, as it allows them to experience predictable and adaptable situations that are free from social stress factors (Sartori et al., 2022; Bottiroli et al., 2023).

In summary, the quantitative data show that the motor skills programme enhanced with virtual reality had a greater impact than traditional methods, with an average improvement of 38% overall in the experimental group compared to 13% in the control group. This was particularly evident among pupils with SLDs, who benefited from the immersive and structured nature of VR. This confirms the inclusive and innovative potential of VR in motor education.

2.2 Qualitative data analysis

Thematic analysis of the interviews revealed significant differences in the perceptions of the curriculum and support among the two groups of teachers, providing descriptive observations and personal opinions on the strengths and weaknesses of the two approaches. Teachers in the control group emphasised the benefits of the social dimension of traditional activities above all, observing improvements in peer collaboration and group rule management. Some curriculum teachers stated that they considered it 'essential for children to learn to relate directly to each other, even when dealing with conflicts and misunderstandings, because these are lifelong skills'. However, a certain concern also emerged: several teachers reported difficulty in maintaining high motivation among children with lower motor skills. They described situations in which some pupils 'became easily discouraged, showing frustration and poor participation'. Support teachers in the control group recognised the importance of inclusive gym activities, but admitted that children with greater fragility sometimes remained on the sidelines, requiring significant mediation to get involved.
In contrast, teachers in the experimental group described virtual reality as a powerful motivational tool capable of stimulating the enthusiasm and curiosity of even the most timid or challenged students. One curriculum teacher stated, 'I finally saw children who usually hide

behind their classmates get involved with enthusiasm, without fear of making mistakes'. Support teachers emphasised how virtual scenarios encouraged the active participation of students with autism spectrum disorders (ASD). One support teacher reported that, for the first time, a student who usually isolated himself spontaneously asked to take part in the activity again because he felt safe in the virtual environment. Curriculum teachers also noted an increase in concentration and perseverance in motor tasks, attributing this to the immediate feedback provided by VR. This allowed children to 'see their progress immediately and correct themselves without feeling judged'.

Both groups recognised the inclusive value of the two approaches, albeit from different perspectives. Teachers in the control group emphasised the irreplaceable importance of real relational dynamics, stressing that 'direct peer relationships remain an educational aspect that no technology can replace'. In contrast, teachers in the experimental group highlighted technology's role as a mediator that 'breaks down motivational and relational barriers, opening up concrete opportunities for participation, even for those who are usually excluded'. In summary, the perceptions gathered show that VR does not replace traditional practices, but can complement and enrich them, offering an alternative context capable of stimulating motivation, confidence and inclusion. Although diverse, teachers' personal opinions converge on the idea that the educational experience is more complete when it combines direct relational interaction with the targeted use of immersive technologies.

3. Discussion

The results obtained confirm the added value of using immersive virtual reality in motor and socio-emotional education programmes, in terms of both quantity and quality. Comparing the results with those of the control group showed that VR promotes a more significant improvement in locomotor skills and object control. This is consistent with recent literature that highlights the role of immersive technologies in enhancing general dynamic coordination, motor dexterity, and the precision of movement (Li et al., 2023; Robinson et al., 2022; Westendorp et al., 2023). Situated learning in virtual environments enables children to experiment with complex activities in safe and repeatable settings, enhancing their ability to apply acquired skills to real-life situations and traditional sports (Estevan & Barnett, 2021; De Meester et al., 2020).

Teachers have also emphasised in their testimonials that VR is perceived as a tool capable of reducing anxiety, frustration and demotivation, while stimulating curiosity, concentration and perseverance. Some teachers have reported increased engagement, even among children who tend to exhibit avoidance behaviours in a traditional context. Studies have shown that the immersive and interactive nature of VR promotes intrinsic motivation thanks to immediate feedback and the possibility of experiencing gradual successes (Radianti et al., 2020; Caggianese et al., 2022; Cheng et al., 2024). Therefore, the playful and multisensory nature of the experience is a key factor in strengthening perceived self-efficacy and consolidating learning.

The impact on pupils with Autism Spectrum Disorders was particularly significant. They showed significant progress in both motor skills and social interactions, benefiting from the predictability and protective nature of virtual scenarios. VR allowed them to enjoy gradual, adjustable experiences that were free from excessive anxiety-inducing stimuli, thus encouraging a greater willingness to participate actively. Recent literature confirms that immersive environments offer these students personalised learning opportunities, reducing social anxiety and promoting prosocial behaviour (Sartori et al., 2022; Bottiroli et al., 2023;

Zhang et al., 2024). In this sense, VR acts as an inclusive mediator that expands the possibilities for interaction and cooperation, strengthening pupils' sense of belonging and helping to reduce isolation.
However, some teachers have emphasised the indispensable value of real peer relationships, stating that VR should be understood as a complementary tool rather than a replacement for authentic physical and social experiences. Contemporary pedagogical reflections reiterate this critical point, emphasising the need to maintain a balance between digital innovation and human contact so that educational technologies become catalysts for meaningful relationships and learning rather than factors of alienation (Immordino-Yang, 2020; Ergas, 2022; Karami et al., 2023).

In this sense, the discussion prompts broader reflection on striking the right balance between traditional and innovative teaching methods, while taking into account the particularities of school settings and the diverse characteristics of students. VR shows great promise when incorporated into an educational project that prioritises physicality, genuine collaboration, and the invaluable role of the teacher as a mediator between technology and students (Tokuhama-Espinosa, 2021; Chen et al., 2024). Therefore, the effectiveness of the intervention lies not only in the technology itself, but also in its integration with inclusive teaching practices that combine digital, physical and relational experiences within a unified and coherent framework.

Conclusions

In conclusion, the study demonstrated that incorporating immersive virtual reality into physical education and sports offers a valuable opportunity to improve motor skills and socio-emotional competencies among primary school children, particularly those with special educational needs. Quantitative data revealed more consistent progress than the traditional approach, while teachers' qualitative perceptions emphasised the high level of motivation and engagement generated by virtual environments. VR is indeed a tool that can expand participation opportunities, strengthen self-efficacy, and reduce anxiety and frustration. This inclusive and personalising potential has already been highlighted in recent studies (Radianti et al., 2020; Sartori et al., 2022; Bottiroli et al., 2023).

Another aspect that has emerged is the ability of VR to stimulate not only motor development, but also the socio-emotional dimension, through cooperative and immersive experiences. This approach is particularly effective in promoting empathy, collaboration, and emotional regulation. This is in line with educational neuroscience evidence that highlights the interconnection between the body, emotions, and cognition in learning processes (Diamond, 2022; Hamilton et al., 2021). These results suggest that VR can create more motivating and engaging learning environments in which even the most timid students or those with social vulnerability can experience significant and progressive success.

At the same time, the results confirm that technology is most effective when used under the guidance of competent educators in an environment that values direct interpersonal relationships. In this sense, the role of the teacher as a facilitator and mediator between technology and students is crucial in transforming the digital experience into an authentic, shared learning journey (Immordino-Yang, 2020; Ergas, 2022; Karami et al., 2023). Furthermore, the conducted experience shows that VR does not replace existing teaching practices, but rather complements and enriches them, offering new scenarios that stimulate attention, motivation and inclusion without compromising the importance of real social interactions (Slater & Sanchez-Vives, 2022; Chen et al., 2024).

Future prospects could involve integrating VR with traditional physical and cooperative approaches to ensure comprehensive learning that combines innovation, physicality, and sociality. In line with the latest Educational Neuroscience perspectives, flexible, multimodal teaching models that can adapt to different learning profiles and exploit immersive technology's potential to promote more inclusive, sustainable educational experiences are necessary (Tokuhama-Espinosa, 2021; Li et al., 2023; Zhang et al., 2024). Further research could explore the long-term impact of VR in greater depth by investigating not only the retention of acquired skills, but also how such experiences influence overall academic motivation, self-regulation, and social integration in different contexts.

Ultimately, this study suggests that, when used consciously and pedagogically, VR is a valuable resource for creating more equitable and stimulating learning environments that enhance student diversity and respond innovatively to contemporary educational challenges.

References

Caggianese, G., Gallo, L., & Neroni, P. (2022). Immersive virtual reality in motor learning: Opportunities and challenges. *Computers & Education, 180*, 104432.

Capio, C. M., Westendorp, M., & Veldman, S. (2022). Gross motor skills and inclusion in physical education: A review. *Adapted Physical Activity Quarterly, 39*(1), 1–18.

Castleberry, A., & Nolen, A. (2018). Thematic analysis of qualitative research data: Is it as easy as it sounds? *Currents in Pharmacy Teaching and Learning, 10*(6), 807–815.

De Meester, A., Stodden, D. F., & Goodway, J. D. (2020). Associations of actual and perceived motor competence with physical activity in children: A cross-sectional study. *Journal of Science and Medicine in Sport, 23*(3), 312–317.

Diamond, A. (2022). Executive functions in children: Insights from developmental cognitive neuroscience. *Annual Review of Developmental Psychology, 4*(1), 301–328.

Estevan, I., & Barnett, L. M. (2021). Fundamental movement skills development in children: Current perspectives. *Sports, 9*(5), 65.

Fraser-Thomas, J., Côté, J., & Deakin, J. (2005). Youth sport programs: An avenue to foster positive youth development. *Physical Education & Sport Pedagogy, 10*(1), 19–40.

Giannakopoulos, G., Tzavara, C., Dimitrakaki, C., Kolaitis, G., Rotsika, V., & Tountas, Y. (2009). The factor structure of the Strengths and Difficulties Questionnaire (SDQ) in Greek adolescents. *Annals of General Psychiatry, 8*(20), 1–9.

Hamilton, D., McKechnie, J., & Edgerton, E. (2021). Immersive virtual reality as a pedagogical tool in education: A systematic literature review. *British Journal of Educational Technology, 52*(4), 1570–1589.

Hoffmann, R., Schultheis, T., & Bäuerlein, K. (2023). Reliability and validity of the Strengths and Difficulties Questionnaire (SDQ) in inclusive classrooms. *European Journal of Special Needs Education, 38*(3), 355–371.

Immordino-Yang, M. H. (2016). *Emotions, learning, and the brain: Exploring the educational implications of affective neuroscience*. W. W. Norton & Company.

Li, X., Sun, M., & Zhu, Y. (2023). The effectiveness of virtual reality on motor skills training: A meta-analysis. *Educational Technology Research and Development, 71*(3), 1121–1145

Lopes, V. P., Rodrigues, L. P., & Maia, J. (2021). Development of motor coordination in primary school children. *European Journal of Sport Science, 21*(2), 223–232.

Mertens, D. M. (2019). *Research and evaluation in education and psychology: Integrating diversity with quantitative, qualitative, and mixed methods* (5th ed.). SAGE.

Miller, M., Jarus, T., & Bart, O. (2019). Participation in leisure activities among children with and without developmental coordination disorder: A comparative study. *Physical & Occupational Therapy in Pediatrics, 39*(3), 269–285.

Niclasen, J., Skovgaard, A. M., & Andersen, A. M. N. (2019). A confirmatory factor analysis of the Strengths and Difficulties Questionnaire in a large population of Danish children. *European Child & Adolescent Psychiatry, 28*(3), 391–402.

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods, 16*(1), 1–13.

Parong, J., & Mayer, R. E. (2021). Cognitive and affective processes in learning from immersive virtual reality: A review and meta-analysis. *Educational Psychology Review, 33*(3), 937–958.

Pietrabissa, G., Manzoni, G. M., & Castelnuovo, G. (2021). The potential of virtual reality in healthcare: A systematic review. *Frontiers in Psychology, 12*, 645153.

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education, 147*, 103778.

Robinson, L. E., Stodden, D. F., & Goodway, J. D. (2022). Motor competence and its effect on physical activity in young children. *Journal of Motor Learning and Development, 10*(1), 45–60.

Rosa, R. A., Silva, G., & Costa, J. (2022). Cooperative games in physical education: Effects on social skills. *Journal of Physical Education and Sport, 22*(4), 1199–1206.

Sartori, R., Gagliardini, G., & Tartarisco, G. (2022). Virtual reality in special education: An Italian case study. *Italian Journal of Special Education, 40*(2), 125–139.

Slater, M., & Sanchez-Vives, M. V. (2022). Enhancing our lives with immersive virtual reality. *Nature Reviews Psychology, 1*(3), 229–239.

Tokuhama-Espinosa, T. (2018). *Neuromyths: Debunking false ideas about the brain*. Cambridge University Press.

Woods, C., Macklin, R., & Lewis, J. (2020). Using NVivo in educational research: A researcher's guide. *International Journal of Social Research Methodology, 23*(2), 135–150.

Zhang, Y., Chen, H., & Liu, Q. (2024). Virtual reality and autism: Effects on social interaction. *Autism Research, 17*(2), 123–137.