ENHANCING MOTOR SKILLS IN SPECIAL NEEDS EDUCATION THROUGH VIRTUAL REALITY: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

This systematic literature review explores the use of Virtual Reality (VR) in special needs education, focusing on its potential to enhance motor skill development in children with disabilities. This review synthesizes findings from various studies to provide a comprehensive overview of the current research landscape. Key themes and methodologies were identified, specific interventions were examined, and the relevance of the findings to an ongoing VR project was discussed. These studies consistently emphasize the effectiveness of interactive VR environments in enhancing motor skills by simulating real-world scenarios, allowing students to practice in a controlled and realistic manner. VR has been shown to create enriched training environments that exploit neuroplasticity for motor recovery and improve motor coordination abilities in children. However, individual differences, such as prior VR exposure, must be considered when utilizing immersive head-mounted VR for motor rehabilitation. While challenges such as cost and technical issues exist, the overall findings indicate that VR is a valuable tool for motor skill enhancement in special needs education. This review highlights the potential of VR to overcome the limitations of traditional methods and provide engaging, personalized learning experiences for children with disabilities.

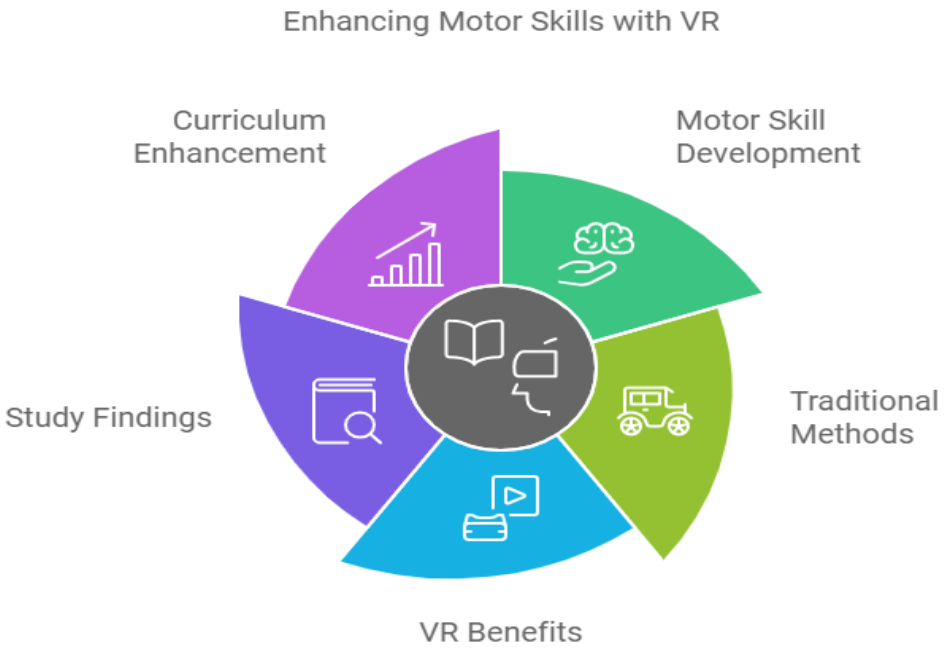
INTRODUCTION

In the ever-evolving realm of special education, the integration of Virtual Reality (VR) represents a pioneering approach in instructional design aimed at overcoming the inherent difficulties faced by conventional teaching methods. The emergence of VR has opened new avenues for creating immersive, interactive, and personalized learning settings, especially in the context of motor skill development among children with special needs. This literature review brings together findings from an extensive

range of studies to provide a comprehensive overview of the current state of research in this area.

The significance of motor skill development in special education cannot be overstated, as it is closely connected to overall cognitive and physical development. Children with disabilities frequently require tailored interventions that consider their limitations and strengths. Traditional methods, such as physical therapy and adaptive physical education, although valuable, sometimes lack the engagement or adaptability necessary for optimal outcomes. This gap has sparked interest in VR as a tool that offers customized, engaging, and adaptable training environments.

This review is organized to examine how existing studies address motor skill development in special education and identify the key themes and methodologies employed. Subsequently, the report delves into specific interventions examined across various studies, highlighting the outcomes and effectiveness of these methods. The final section discusses the relevance of these findings to our ongoing VR project, focusing on how the insights gained can be practically applied to enhance the curriculum.



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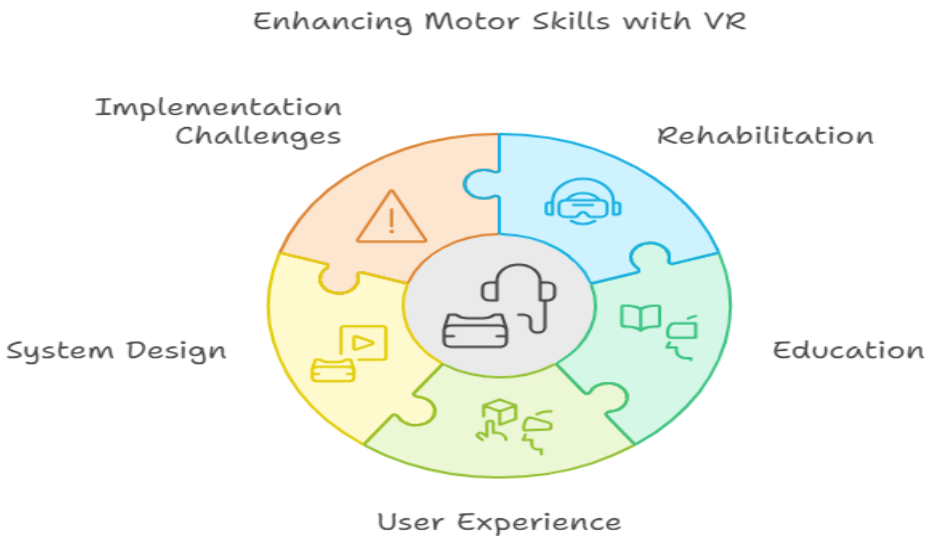
Summary of the Results of Research

Methods for investigating motor skill development in special-needs education

The reviewed studies focused on the critical role that motor skill development plays in the broader context of special needs education. The primary challenge addressed by these studies is the need to create engaging, effective, and accessible learning environments that accommodate the diverse abilities of disabled students.

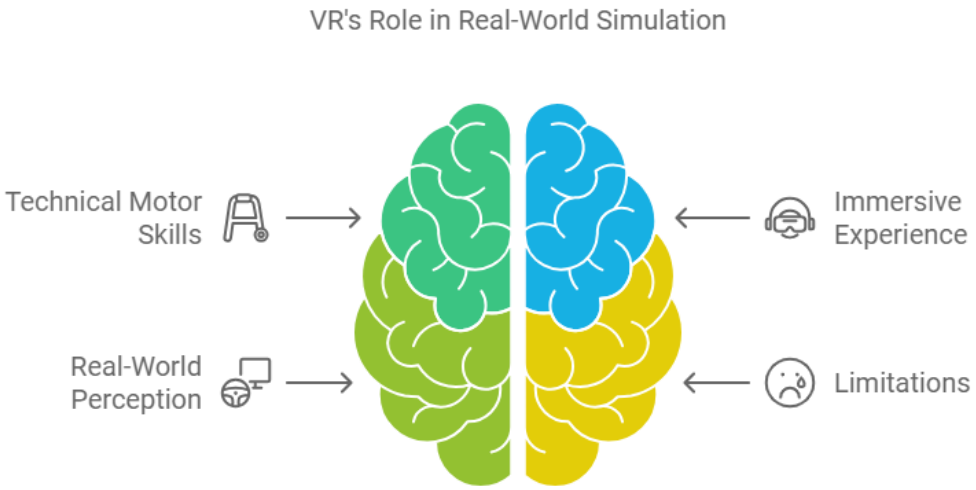
1. Research has demonstrated that VR environments can enhance motor skills in diverse populations. For example, Utamayasa and Mardhika (2024) investigated the use of VR in special education settings and found that these environments could simulate real-world scenarios, allowing students to practice motor skills in a controlled and realistic manner. This approach is particularly beneficial for students with physical disabilities, as it provides them with opportunities to engage in activities that might be challenging or risky in real life. Moreover, VR has been found to create enriched training environments that exploit neuroplasticity for motor recovery (Levin et al., 2015). Immersive VR combined with wearable haptics has also been shown to be engaging and adaptable to children with neuromotor impairments (Bortone et al., 2018). Additionally, interactive VR software has a significant positive impact on motor development and confidence among elementary school children (Utamayasa & Mardhika, 2024). However, it is imperative to consider individual differences when using immersive head-mounted VR (HMD-VR) for motor rehabilitation. Prior exposure to HMD-VR may affect the transfer of learned motor skills to non-VR environments (Juliano et al., 2019). Furthermore, VR can increase student motivation and engagement; however, challenges such as cost and technical issues must be addressed (Paramita et al., 2024). A systematic review by Komaini et al. (2024) also supported the role of VR in enhancing motor coordination abilities in children with

positive responses to VR interventions. In summary, evidence suggests that interactive VR environments are effective in improving motor skills, with applications ranging from rehabilitation (Bortone et al., 2018; Levin et al., 2015; Sisto et al., 2002) to education (Paramita et al., 2024; Stavroulia et al., 2019; Utamayasa & Mardhika, 2024). The effectiveness of VR is influenced by factors such as the design of the VR system, the user's prior experience with VR, and the specific needs of the population being served. Although there are challenges to its implementation, the overall findings are positive, indicating that VR is a valuable tool for motor skill enhancement (Levin et al., 2015).



2. Real-world simulation: The ability of VR to simulate real-world environments has been widely studied and documented. Aslanov et al. (2022) conducted a study focused on students with lower limb disabilities and highlighted the use of VR to practice technical motor skills, such as walking, balance, and coordination. The study found that students who engaged in VR simulations showed significant improvements in these areas, primarily because of the immersive and interactive nature of the VR experience, which motivated them to practice more consistently and with greater focus. The ability of VR to simulate real-world environments is a recurring theme in the literature. Studies have demonstrated that VR can effectively replicate aspects of real-world settings, leading to similar perceptions and behaviors among users (Jin et al., 2022). For instance, VR has been shown to produce similar rankings of perceived

healthiness in a virtual shopping environment as in a real-life setting (Xu et al., 2020) and to replicate real-world perceptions of brightness, glare, and spaciousness in interior design research. However, there are some limitations to consider. Although VR can simulate many real-world attributes, the fidelity of these simulations can vary, and certain sensory experiences may not be fully replicated. For example, visual acuity tasks performed in VR environments do not match performance in real-world conditions, and the psychological processes influencing behavior in VR, such as spontaneous mental simulation, may differ from those in actual reality (Tal & Wansink, 2011). Additionally, the external validity of VR simulations, particularly in the context of shopper behavior, remains an area of limited evidence (Zhao et al., 2022). In summary, VR technology has shown considerable promise in simulating real-world environments, with studies indicating that it can elicit perceptions and behaviors similar to those in real-life contexts.



3. Task-oriented and adaptive training: In their comprehensive review of VR-based interventions for improving motor skills in children with developmental disabilities, Fu and Ji (2023) highlighted the unique advantages offered by VR in providing task-oriented training that is both adaptive and responsive to learners' needs. Adaptability is essential for special-needs students, who often require personalized learning paths to achieve optimal outcomes. The reviewed studies indicated that VR

offers a unique advantage in task-oriented training, which is adaptive and responsive to learners' needs. VR simulations provide tailored learning experiences that can be standardized and cater to different learning styles, allowing trainees to develop skills at their own pace and repeat specific scenarios to remedy skill deficiencies (Ruthenbeck & Reynolds, 2015). Furthermore, VR training simulations are customizable with settings that can be modified to suit personal or professional preferences, thus facilitating meaningful learning through personalized feedback (Heibel et al., 2024). However, it is important to note that while VR technology is highly beneficial for various training purposes, there are limitations, such as the lack of realistic haptic feedback in some simulators (Ruthenbeck & Reynolds, 2015) and challenges for low-achieving students who may encounter difficulties in self-regulating their learning in VR environments (Wang et al., 2024). Despite these limitations, VR has been shown to enhance performance in diverse fields, such as welding (Heibel et al., 2024), the building industry (Vassigh et al., 2024), manufacturing (Nayak et al., 2024), and even CPR training (Barsom et al., 2020), demonstrating its adaptability and responsiveness to different learning needs.

In essence, the literature suggests that VR is beneficial for task-oriented training owing to its flexibility and capacity to deliver personalized learning experiences. This conclusion is reinforced by the results of studies that demonstrate significant improvements in learning outcomes for struggling students who used VR in conjunction with learning aids (Wang et al., 2024), as well as the transformative effects of VR on conventional teaching methods (Shaukat, 2023), and its successful application in specialized training contexts, such as self-defense for medical professionals (Ivanov, 2023) and cardiopulmonary resuscitation (CPR) for high school students (Barsom et al., 2020). These findings indicate that VR adaptability and responsiveness are well documented across a range of educational and professional domains.

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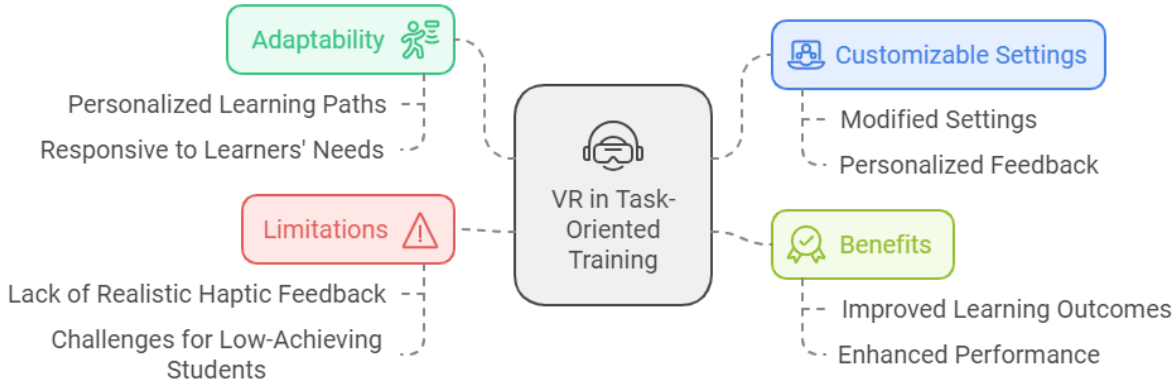
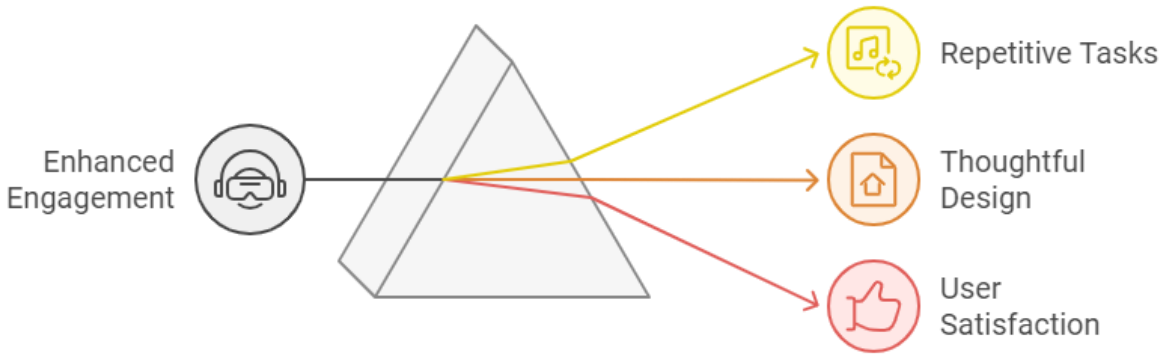


4. Engagement and motivation: There is general agreement in the academic community that VR significantly improves student engagement and motivation, which are key factors in the success of motor skill development programs. Conventional methods may struggle to maintain student interest, especially when repetitive exercise is necessary. On the other hand, VR offers a dynamic and engaging environment that can make repetitive tasks feel fresh and exciting. This heightened engagement often results in better adherence to practice, leading to enhanced motor skills. VR transforms the engagement level of tasks that might otherwise be considered repetitive. The immersive nature of VR provides a sense of presence and agency that can significantly enhance the user experience and satisfaction (Dai, 2024). This is particularly evident in the context of industrial training, where VR has been shown to reduce training time and improve safety and productivity by providing realistic hands-on experiences (Nayak et al., 2024). Interestingly, while VR can make repetitive tasks feel novel and engaging, the literature suggests that the design of the VR environment plays a crucial role in this perception. For instance, the presence of obstacles in a VR landscape can restrict movement and reduce the sense of presence, which might detract from engagement (Saorin et al., 2023). Moreover, the social and interactive dimensions of VR experiences can further influence user engagement, with shared VR experiences eliciting more positive affect (Guertin-Lahoud et al., 2023). VR has the potential to rejuvenate repetitive tasks by creating dynamic and engaging environments. The efficacy of VR in enhancing task engagement is influenced by the design of the VR

environment and the interactive and social elements incorporated into the experience. These findings emphasize the importance of thoughtful VR design in maximizing user engagement and satisfaction (Dai, 2024; Guertin-Lahoud et al., 2023; Nayak et al., 2024; Saorin et al., 2023).

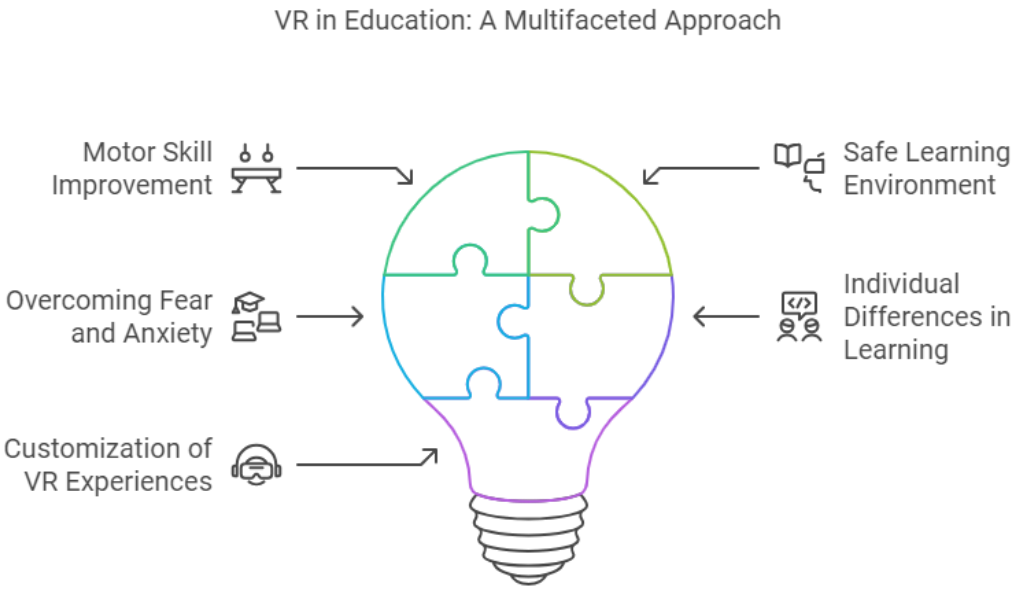


Interventions and outcomes

The interventions reviewed in the literature vary widely, from VR-based physical education sessions to complex immersive simulators designed to replicate real-world tasks. The outcomes of these interventions have generally been positive, with most studies reporting significant improvements in motor skills among participants.

1. VR-Based Physical Education Sessions: Utamayasa and Mardhika (2024) conducted a study on the application of VR in physical education settings where students engaged in activities such as virtual sports and movement-based games. The results of this intervention revealed significant improvements in students' motor skills, including balance, coordination, and agility. Additionally, the VR environment provided a secure space for students to practice movements they might otherwise avoid because of fear of injury or failure. The studies reviewed indicate that VR environments offer a secure setting for individuals to engage in activities that they might otherwise avoid because of fear of injury or failure. For example, VR has been used to simulate high-risk scenarios, such as public speaking in a foreign language (Kaplan-Rakowski

& Gruber, 2023), technical skills such as car detailing (Tai et al., 2022), and confronting phobias (Khaliq et al., 2018; Loucif et al., 2021; Suyanto et al., 2017). These environments allow for repeated exposure and practice without real-world consequences, thereby reducing anxiety and improving performance. Although VR provides a safe space for practice, it also presents unique challenges. For example, low-achieving students may struggle with self-regulation in VR learning environments (Wang et al., 2024), and the effectiveness of VR in reducing fear may depend on individual differences, such as sensation seeking and neuroticism (Lin, 2017). Additionally, learning outcomes in VR can be influenced by factors such as self-efficacy, learning interest, and flow experience (Tai et al., 2022). In conclusion, VR environments undoubtedly provide a secure setting for the exploration and acquisition of skills, eliminating the possibility of physical harm or inadequacy. Studies have shown that VR can alleviate anxiety associated with public speaking, enhance technical proficiency, and assist in overcoming phobias. Nevertheless, the utility of VR as a learning medium may be subject to the unique traits of individual learners and the layout of the VR experience. Consequently, VR serves as a valuable means of risk-free practice, but its execution should be carefully customized to cater to the specific requirements and aptitudes of the learner.



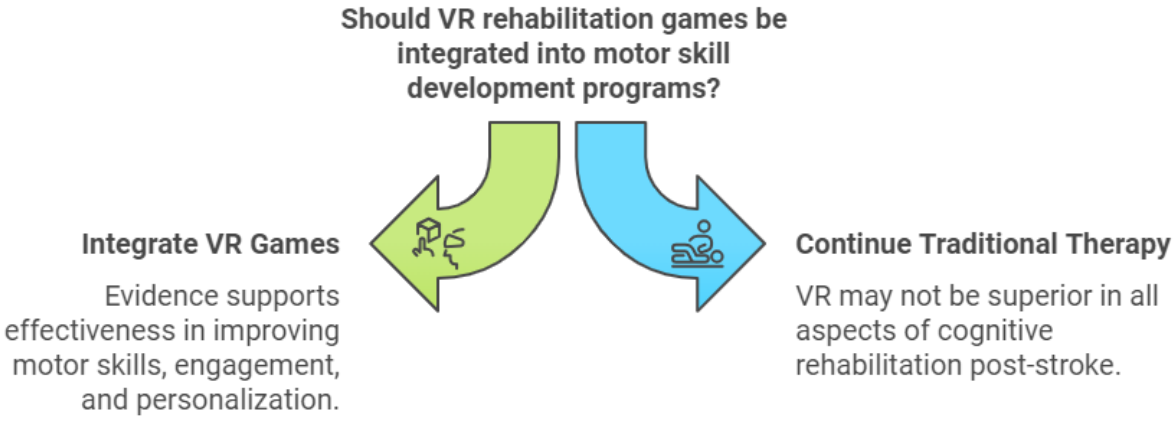
2. Immersive virtual simulators: In a study conducted by Aslanov et al. (2022), immersive virtual simulators were used to aid students with lower-limb disabilities in practicing walking and balance. The simulator provided a realistic walking environment with obstacles and varying terrains. The participants in these sessions exhibited considerable improvements in their ability to navigate real-world environments. Moreover, the study reported an increase in student confidence, as the VR environment allowed them to practice without fear of public failure or judgment. The application of VR in educational settings has been linked to an increase in student confidence, particularly as it offers a safe space for practice without fear of public failure or judgment. This is supported by the findings of Barsom et al. (2020), which indicate that high school students who underwent VR-enhanced cardiopulmonary resuscitation (CPR) training displayed higher self-confidence in performing CPR than those who received conventional training. The immersive nature of VR allows students to engage in realistic scenarios, thereby reducing the anxiety associated with real-life applications of their skills (Barsom et al. 2020).

Interestingly, although increased confidence is a significant advantage, it is not the sole benefit of VR in education. Immersive VR environments also contribute to an improved understanding of complex concepts and decision-making (Yahaya, 2006), as well as heightened student motivation and engagement (Paramita et al., 2024). These factors collectively suggest that VR technology not only bolsters confidence but also enhances the overall learning experience. VR has the potential to enhance learning environments in several ways. For instance, it can help mitigate the fear of public failure and boost self-confidence among students (Barsom et al., 2020). This, in turn, may lead to better learning outcomes as students become more engaged with the material and apply their knowledge in a simulated yet realistic setting (Paramita et al., 2024; Yahaya, 2006). Evidence suggests that VR technology has substantial potential for educational applications and may transform traditional learning paradigms by providing a safe, immersive, and interactive experience (Barsom et al., 2020; Paramita et al., 2024).

3. VR rehabilitation games: The research conducted by Fu and Ji (2023) evaluated multiple studies that utilized VR rehabilitation games for motor skill development. These games were specifically designed to target motor skills, such as hand-eye coordination, fine motor control, and functional balance. The review revealed that these games demonstrated a high degree of effectiveness in improving targeted skills, with the majority of participants exhibiting measurable enhancements following several weeks of training. The interactive nature of games and the immediate feedback provided to players are considered key factors contributing to their success.

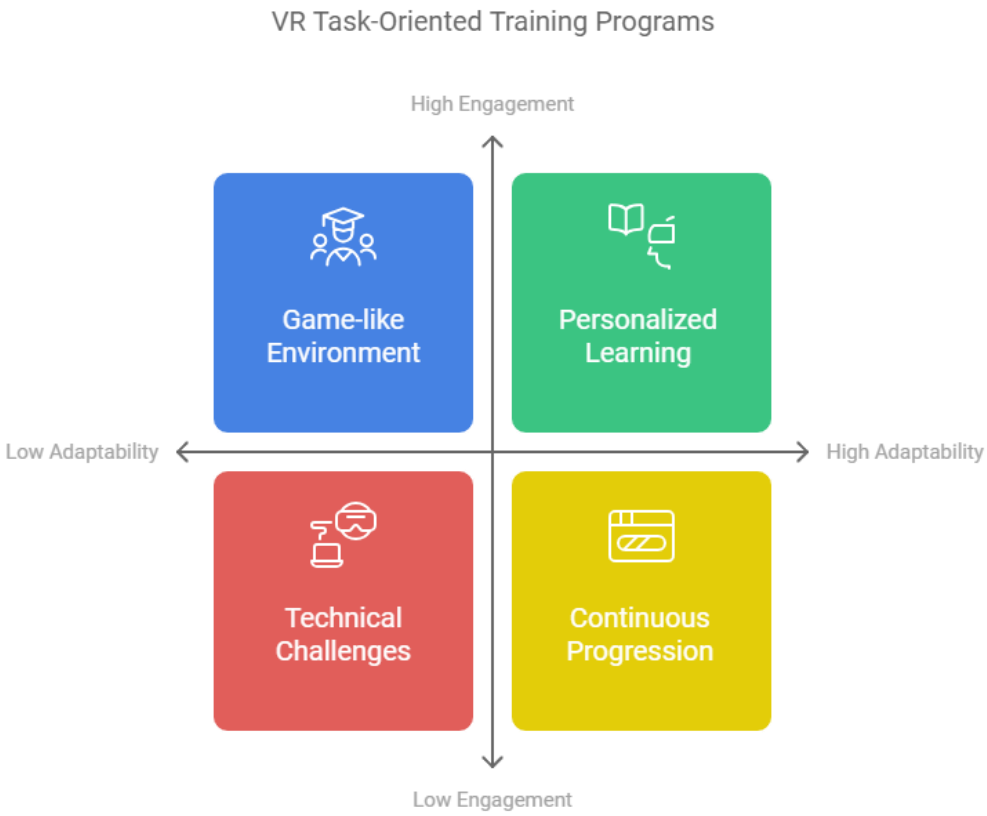
VR rehabilitation games are increasingly recognized as valuable tools for motor skill development, especially in individuals with neurological disorders and in those recovering from events such as stroke. These games offer an engaging platform for patients to perform repetitive physical exercises that are essential for motor skill acquisition and rehabilitation. The immersive nature of VR, along with the adaptability of game scenarios, enables the creation of personalized and motivating therapy sessions that can be adjusted according to a patient's abilities and progress. Although VR rehabilitation games are generally well received and show promise in improving motor functions, some studies suggest that VR therapy may not be superior to

traditional therapy in all aspects of cognitive rehabilitation post-stroke (Wiley et al., 2020). However, regarding motor skill development, VR interventions have been demonstrated to be effective, often resulting in improved outcomes compared with conventional methods. In conclusion, VR rehabilitation games represent an innovative and effective approach for motor skill development in various patient populations. They offer a customizable, engaging, and potentially motivating alternative to traditional therapeutic methods. Although further research is needed to fully understand the scope of their efficacy, current evidence supports the integration of VR games into rehabilitation programs to enhance motor skill recovery and development.



4. Task-oriented training programs: Several studies reviewed by Fu and Ji (2023) have focused on task-oriented training programs, which involve students performing specific tasks designed to improve particular motor skills. These tasks are often embedded in a game-like environment, making them more engaging for students. The review emphasized the effectiveness of task-oriented training in a VR setting, which can be easily adapted to each student's individual needs. For example, tasks could be made more challenging as a student's skills improve, ensuring a continuous progression towards more advanced motor abilities. The adaptability of task-oriented training in VR settings is underscored by its effectiveness in facilitating personalized learning experiences by allowing adjustments to the training environment that cater to the specific requirements of each student (Nayak et al., 2024; Paramita et al., 2024;

Shaukat, 2023). This individualized approach is beneficial in educational settings where diverse learning styles and paces must be accommodated. However, VR adaptability also presents challenges, such as the need for specialized equipment and potential technical issues (McIntyre, 2023; Paramita et al., 2024). Despite these challenges, the immersive nature of VR and its capacity for customization make it a powerful tool for task-oriented training, as it can enhance engagement and improve the understanding of complex concepts (Lau & Chen, 2009; Paramita et al., 2024). In conclusion, VR's ability to provide tailored task-oriented training is highly effective owing to its immersive and interactive qualities, which can be fine-tuned to meet individual learning needs. While there are obstacles to overcome, research indicates that the benefits of personalized VR training experiences are substantial, leading to increased motivation, engagement, and potentially better learning outcomes (Nayak et al., 2024; Paramita et al., 2024; Shaukat, 2023).



CONCEPTUAL FRAMEWORK OF THE PROJECT

Framework

The findings of the literature review provide critical insights that can directly inform the development of our VR project. The consistent success of VR in enhancing motor skills across diverse student populations indicates that our project is well-positioned to have a significant impact on special needs education.

1. Customizable Learning Experiences: One of the central messages that emerges is the significance of creating personalized learning experiences that cater to the specific needs of each student. The adaptable nature of VR enables us to devise interventions that are not only effective, but also scalable to varying proficiency levels. This means that our VR curriculum can offer a comprehensive range of difficulty levels, from fundamental motor skill exercises to more intricate, goal-oriented tasks. The extant literature supports the contention that VR curricula can provide a spectrum of difficulty levels, ranging from basic motor skills to intricate task-oriented activities. Raison et al. (2016) established benchmarks for competency in robotic surgery within a VR training curriculum, indicating that VR can be tailored to various skill levels from beginners to experts (Raison et al., 2016). Carrera et al. (2024) further exemplify the adaptability of VR to different motor tasks by presenting a framework that facilitates the design of VR tasks that mimic natural motions, which can be adjusted for individual capabilities and practice effects (Carrera et al., 2024). Moreover, Houzangbe et al. (2023) underscores the potential of VR to deliver 'just-right' challenges by adjusting task parameters, which is critical for motor learning in pediatric rehabilitation (Houzangbe et al., 2023).However, it is important to note that while VR can offer a wide range of difficulty levels, the effectiveness of training may be influenced by factors such as the user's arousal levels (Radhakrishnan et al., 2021) and the fidelity of the VR environment to real-world tasks, as seen in the context of microgravity (Panait et al., 2006). Moreover, the development of a proficiency-based VR curriculum for advanced laparoscopic procedures (Palter et al., 2011) and a structured VR curriculum for laparoscopic appendicectomy (Sinitsky et al., 2019) both illustrate the application of

VR to complex surgical training, reinforcing the versatility of VR curricula. In summary, evidence suggests that VR curricula are capable of encompassing a broad range of difficulty levels, from foundational motor skills to advanced, specialized tasks. This is achieved through careful design and implementation of VR training programs that can be personalized and adjusted to learners' needs, thereby facilitating a comprehensive and effective training experience (Carrera et al., 2024; Houzangbe et al., 2023; Palter et al., 2011; Raison et al., 2016; Sinitsky et al., 2019).

2. Engagement-driven design: The following excerpt emphasizes the importance of engagement in the success of motor skill interventions. Our VR project should prioritize creating immersive and interactive experiences that maintain students' interests, which may involve using gamification elements. The literature indicates that immersive and interactive VR experiences are crucial for capturing and maintaining student interest and can significantly increase motivation and engagement. The use of VR in educational settings has been linked to positive outcomes, such as enhanced empathy, communication skills, and learning continuity, especially in response to disruptions such as global pandemics. However, challenges such as implementation costs, content development, and accessibility must be addressed to realize the potential benefits of VR in education. Additionally, the literature suggests that the effectiveness of VR can vary depending on factors such as learner engagement, learning domain, and specific VR technology used. Therefore, prioritizing the creation of immersive and interactive VR experiences aligns with the current research, which indicates that such experiences can significantly enhance student engagement and learning outcomes.

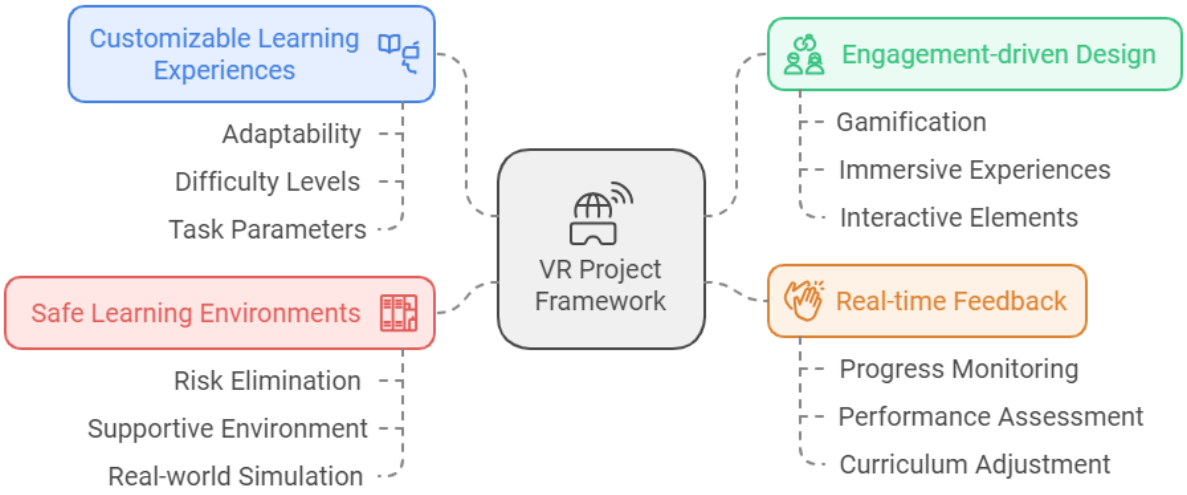
3. Real-time feedback and progress monitoring: The incorporation of real-time feedback, as reported in the literature, is a vital component that can be integrated into our VR curriculum. By delivering prompt feedback on student performance, educators can help students assess their progress and identify areas that require improvement. Moreover, monitoring progress over time allows instructors to modify the curriculum according to each student's evolving requirements, ensuring that interventions remain effective throughout the learning journey. The literature demonstrates that real-time

feedback is a useful element in educational contexts, particularly when integrated into VR curricula. Singh and Awasthi (2024) examined the use of wearable devices in physical education, which provide immediate feedback on physical activity levels and performance, suggesting that such feedback can enhance student engagement and learning outcomes. Algarni et al. (2024) stress the benefits of utilizing VR simulations in dental education, where immediate feedback on performance can lead to substantial improvements in knowledge, confidence, and psychomotor skills. However, it is essential to consider certain nuances. Although real-time feedback provided by VR applications is generally considered beneficial, the literature does not consistently examine the specific impact of real-time feedback across all educational situations.

For example, Huai et al. (2024) reported that VR technology, which likely includes real-time feedback mechanisms, enhances learning satisfaction, knowledge, and skill performance in nursing education. However, the effects on other aspects, such as motivation and cognitive load, were not significant, suggesting that the effectiveness of real-time feedback may vary depending on the educational outcomes being measured. In summary, the incorporation of real-time feedback into VR curricula is supported by the literature as a means of improving various aspects of learning and skill acquisition (Algarni et al., 2024; Huai et al., 2024; Singh & Awasthi, 2024). While evidence points to the effectiveness of such feedback, it is crucial to recognize that its impact may differ based on the specific educational context and outcomes of interest. Further research could elucidate the conditions under which real-time feedback in VR is most effective, thereby optimizing its integration into diverse educational programs.

4. Safe and controlled learning environments: The use of VR to create safe and controlled environments for practice is a significant advantage that cannot be overlooked. Students with physical disabilities, for instance, may find it challenging to practice motor skills in the real world because of the risk of injury or failure. VR eliminates these risks by offering a platform on which students can experiment and learn without fear. This aspect of VR is particularly valuable in special-needs education, in which creating a supportive and non-threatening learning environment is critical. Several studies across various disciplines have demonstrated the effectiveness of

immersive VR in creating safe and controlled environments. For instance, children with autism spectrum disorder (ASD) can master safety skills in a VR setting, which translates into real-world environments (Dixon et al., 2019). Similarly, VR has been shown to provide a safe space for human resource development, allowing for the practice of soft skills without real-world consequences (Palmas et al., 2019). In biopharmaceutical engineering, VR facilitates repeated practice in a safe context, which is particularly beneficial given the limited access to physical equipment (Chen et al., 2020). Although VR offers a controlled environment, the fidelity of the simulation and the cost of technology are potential drawbacks (Chang & Weiner, 2016). VR has been increasingly recognized as a valuable tool for creating safe and controlled environments for practice across various fields. Despite some limitations, the overall trend suggests that VR's benefits of VR in providing risk-free training environments outweigh its disadvantages. For example, in medical education, VR and robotic simulators provide realistic experiences without putting patients at risk (Salimova, 2024), and in manufacturing, VR training enhances safety and productivity (Nayak et al., 2024). In addition, VR can replace the use of real animals in training, thus adhering to ethical standards (Tang et al., 2021), and shows promise in orthopedic surgery for training and pain management (Combalia et al., 2023). The use of VR in physical training also improves engagement and performance in students (Kumar, 2022), highlighting the broad applicability of VR in safe practice environments. In summary, the literature consistently supports the notion that VR is an effective tool for creating safe and controlled environments in various fields. This capability is crucial for risk-free training and skill development, which is particularly important in high-stakes industries such as healthcare, engineering, and manufacturing. Evidence suggests that VR's immersive nature allows for the replication of real-world scenarios without associated risks, thereby enhancing learning outcomes and safety competencies.



Content of the VR Curriculum

Based on the findings of this literature review, several specific insights and methods can be integrated into our VR curriculum to enhance its effectiveness.

1. Task-oriented and adaptive training programs: The literature suggests that task-oriented and individualized training programs can be highly effective, as demonstrated by Fu and Ji (2023). These programs should include a variety of tasks that target specific motor skills and adjust the difficulty level in real time based on student performance. Research supports this approach, with Schweighofer et al. (2012) discussing the design of task-oriented robots for stroke rehabilitation and Ulbricht et al. (2013) outlining the German Tennis Federation's use of individualized fitness programs based on physical testing results. However, it is important to note that while task-oriented and individualized training is beneficial in certain contexts, its effectiveness can vary based on the domain of application and the characteristics of learners. Dubeau et al. (2016) highlight the motivational and individual characteristics of vocational training students, suggesting that tailored teaching practices could improve student success. Clason et al. (2023) also supports the notion that individual psychological needs and motivation are significant predictors of student success in athletic training programs. In summary, the literature supports the assertion of Fu and Ji (2023) regarding the efficacy of task-oriented and individualized training programs

designed to meet the unique needs of learners, leading to improved engagement and outcomes in various educational and rehabilitative settings (Schweighofer et al., 2012; Ulbricht et al., 2013).

2. Real-time feedback mechanisms: Utilizing real-time feedback within VR activities can aid students in comprehending their progress and making necessary modifications. This can be accomplished through the use of visual and auditory cues within the VR environment, which provides students with immediate feedback on their performance following task completion. The incorporation of real-time feedback into VR activities has been shown to enhance student learning experiences, as demonstrated by Hao (2024). The author found that the WOFERC-enhanced VR platform, which included real-time feedback, significantly improved student performance and engagement in practical assessments. This suggests that real-time feedback in VR can help students understand their progress and make necessary adjustments (Hao, 2024). While the benefits of real-time feedback are clear, the literature also identifies challenges that need to be addressed, such as the need for sufficient faculty training and technological accessibility to effectively leverage VR in teaching (Mallik & Aithal, 2024). These challenges highlight the importance of considering the practical aspects of implementing real-time feedback in VR activities. In conclusion, the integration of real-time feedback within VR activities has been demonstrated to be advantageous for student learning, as it allows for an immediate understanding of progress and the opportunity to make adjustments. However, it is essential to address the associated challenges to maximize the effectiveness of VR as a pedagogical tool. Future research and development should focus on overcoming these barriers to enhance the educational value of VR technology (Hao, 2024; Mallik & Aithal, 2024).

3. Multisensory stimulation: To improve the learning experience, it is crucial to include multisensory stimulation in our VR curriculum, engaging not only the visual and auditory senses, but also leveraging haptic feedback whenever feasible. This approach can reinforce motor learning by providing a more immersive and realistic experience, as suggested in the literature. The systematic review conducted by Apostolou and

Liarokapis (2022) supports the idea that multisensory VR systems that incorporate haptic feedback can enhance user experience, with the majority of studies demonstrating positive effects. This is further corroborated by Gibbs et al. (2021), who found that haptic feedback, in conjunction with visual cues, can increase the sense of presence in VR. Additionally, Kim et al. (2022) demonstrated that multisensory pseudo-haptic feedback can effectively simulate weight perception, suggesting that haptic feedback can enrich the VR experience by providing more realistic interactions. Gao et al. (2024) also emphasized the value of haptic feedback, showing that bimanual haptic feedback can improve spatial search tasks in VR, potentially offering a more intuitive and efficient user experience. However, it is important to note that while haptic feedback is beneficial, it is not yet a standard feature in consumer VR products, as indicated by Gibbs et al. (2021). The incorporation of haptic feedback into the VR curriculum should consider the complexity and potential intrusiveness of such stimuli, as indicated by Pietra et al. (2021), who found that haptic feedback was slightly more intrusive than visual feedback, despite its effectiveness in promoting eco-sustainable driving behavior. Overall, the use of multisensory stimulation, including haptic feedback, in the VR curriculum is supported by research findings. Haptic feedback can enhance the sense of presence (Gibbs et al., 2021), improve the perception of weight (Kim et al., 2022), and aid spatial navigation (Gao et al., 2024), resulting in a more immersive and effective learning experience. However, it is important to carefully design and implement haptic feedback to balance its benefits with the potential intrusiveness and limitations of consumer VR technology (Pietra et al., 2021). Therefore, while haptic feedback integration is advisable, it should be done thoughtfully and in conjunction with other sensory modalities to optimize the VR curriculum.

4. Gamification elements: Incorporating gamification elements into VR curricula is a viable solution to enhance student engagement. This can include point systems, progress bars, and rewards for achieving certain milestones, which can make the learning experience more game-like and increase students' motivation to participate actively and consistently, ultimately leading to improved learning outcomes. Research supports the integration of gamification elements into VR curricula to enhance student engagement. Studies have shown that gamification strategies, such as point-based

assessments and competitive dynamics, can significantly increase student motivation and engagement in learning English as a Foreign Language (EFL) (Hardianti, 2024). The integration of VR applications and wearable devices in physical education has been found to create interactive and adaptable learning environments that cater to students' diverse needs and interests, thereby enhancing engagement and learning outcomes (Singh & Awasthi, 2024). However, it is essential to recognize that while gamification can be beneficial, its impact may vary depending on the subject matter. For example, high abstract focus areas such as algebra may not be as suitable for VR-based instruction combined with gamification (Sun & Chen, 2023). Nevertheless, the effectiveness of gamified VR learning environments has been positively evaluated across various educational levels and subjects, indicating that this approach can enhance motivation, engagement, and learning outcomes (Lampropoulos and Kinshuk 2024). In conclusion, the incorporation of gamification elements into VR curricula appears to be a promising strategy for increasing student engagement. Research suggests that gamified VR can provide immersive and interactive experiences that motivate students and improve their learning experiences (Hardianti, 2024; Lampropoulos & Kinshuk, 2024; Singh & Awasthi, 2024). However, educators should consider the suitability of gamification for specific subject matter and learning objectives as well as the potential challenges in implementation (Sun & Chen, 2023). Overall, evidence supports the use of gamified VR as an effective educational tool with the potential to enhance learning across various educational contexts (Chen et al., 2023; Lampropoulos & Kinshuk, 2024).

5. Progressive difficulty: As students hone their abilities, tasks in the VR environment become increasingly difficult. This approach is supported by Fu and Ji (2023) and aligns with the educational strategies outlined in the literature. For instance, the Enhance VR application offers daily cognitive workouts that adapt to user performance and may become more challenging over time (Brugada-Ramentol et al., 2022). The VIRTUE application for cognitive rehabilitation post-stroke also employs gamification techniques to progressively increase task difficulty (John et al., 2019). Although progressive challenge is a common theme, its application varies across contexts. For instance, an immersive VR environment designed for upper limb

rehabilitation presents tasks that are not only challenging, but also enjoyable and closely related to everyday gestures, enhancing the transfer of acquired motor skills to real-life routines (Fregna et al., 2022). This suggests that the principle of progressive difficulty is not only beneficial for cognitive and skill development, but also for rehabilitation and the transfer of skills to daily activities. In conclusion, the literature supports the notion that tasks in VR environments should become increasingly challenging as students develop their skills to facilitate continuous learning and skill acquisition. This approach is evident in cognitive training systems (Brugada-Ramentol et al., 2022), rehabilitation (Fregna et al., 2022), and cognitive rehabilitation (John et al., 2019), indicating its broad applicability and potential benefits across domains and user needs.

6. Collaboration with educators and therapists: The implementation of a VR project in special needs education necessitates the active involvement of both educators and therapists. The combination of their expertise will ensure that the curriculum is not only educational but also therapeutic, addressing the holistic needs of students with disabilities. This collaborative approach is crucial for the effective integration of VR into special needs education, as it aligns educational content and therapeutic interventions with best practices. Although the importance of interdisciplinary collaboration is well documented, there are challenges to its implementation, such as educators feeling unprepared for meaningful participation. Therefore, structured professional development and willingness to adapt to new collaborative models are necessary to overcome these obstacles (Dillon et al., 2021; Surender, 2023; Mueller et al., 2018; Nam, 2021).

By integrating these insights and methods into our VR curriculum, we can create a comprehensive and effective educational tool that supports motor skill development in students with special needs. This approach will help us achieve our project goals and have a meaningful impact on the field of special needs education.

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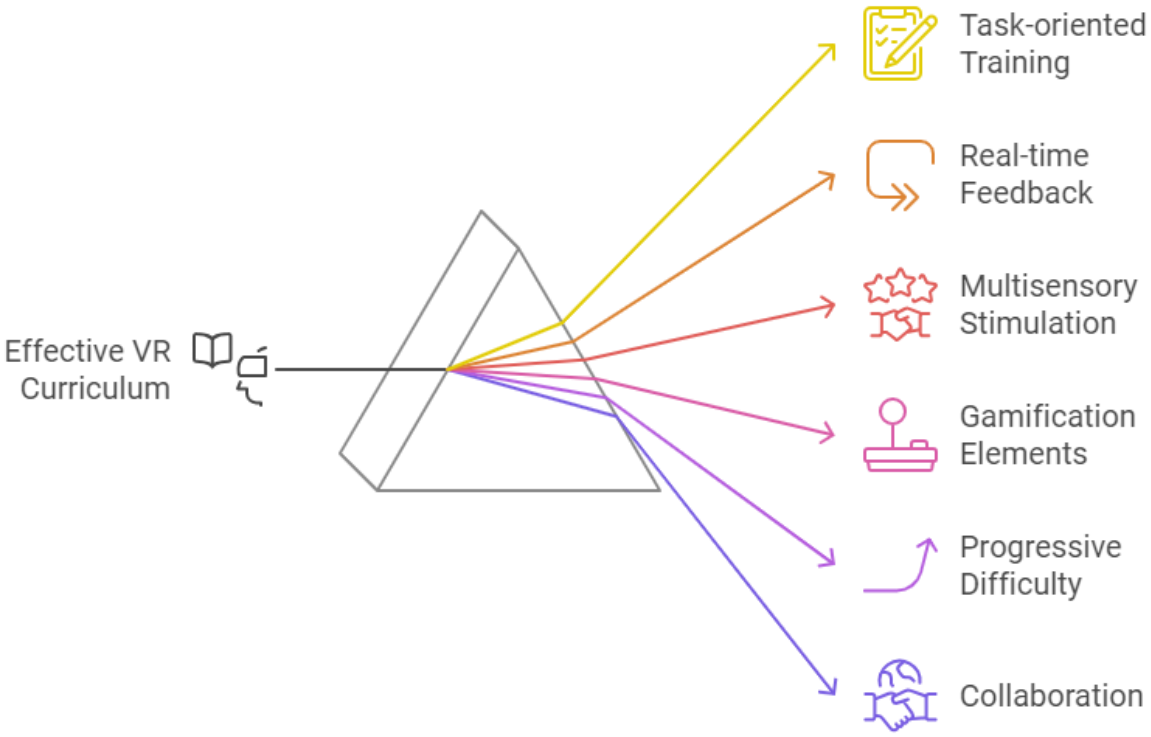

SUMMARY

- VR offers immersive, interactive, and personalized learning settings for motor skill development.
- VR environments can simulate real-world scenarios, allowing students to practice their motor skills in a controlled manner.
- VR creates an enriched training environment that exploits neuroplasticity for motor recovery in diverse populations.
- The interactive VR software had a significant positive impact on motor development and confidence among children.
- Individual differences and prior VR exposure should be considered when using VR for motor rehabilitation.
- VR can increase student motivation and engagement, but challenges such as cost and technical issues exist.
- Evidence suggests that VR is a valuable tool for motor skill enhancement in special needs education.

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