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Designing TANGKAS-VR: Task-Specific Virtual Reality for Motor Skills in Children with Mild Cerebral Palsy

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ABSTRACT

Children with mild cerebral palsy (CP) need intensive, task-specific motor practice, yet such practice is difficult to sustain in special schools. This study aimed to design a virtual reality (VR) learning medium grounded in task-specific motor learning and to examine its feasibility and acceptability. This article reports the first cycle of a six-stage design-based research approach adapting the ADDIE model. Four experts validated the product using two 17-item scales analyzed with Aiken's V, and a limited trial with one child with mild CP used an A1–B–A2 single-subject design with nine task-performance indicators. The resulting prototype, TANGKAS-VR, is a smartphone-based virtual kitchen in which the child prepares soup through functional tasks supported by video modeling, progressively sequenced tasks, and immediate feedback. Expert validation indicated high validity for the special education (V = 0.89) and media aspects (V = 0.86), with operational ease and technical safety rated moderate. Task-performance scores increased from 2 (A1) to 14 (B) and 16 (A2) out of 18, with the largest gains in interaction with virtual objects, whereas task completion and independence still required assistance. The first prototype appears feasible and acceptable, providing a revision agenda for the next cycle and a basis for efficacy trials.

Keywords: *Cerebral Palsy; Virtual Reality; Task-Specific Motor Learning; Design-Based Research; Special Education*

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INTRODUCTION

Cerebral palsy (CP) describes a group of permanent disorders of the development of movement and posture that cause activity limitation. These disorders are attributed to non-progressive disturbances in the developing brain and are often accompanied by disturbances of sensation, perception, cognition, and communication (Rosenbaum et al., 2007). The prevalence of CP is estimated at 1.6 per 1,000 live births in high-income countries and may reach 3.4 per 1,000 live births in low- and middle-income countries (McIntyre et al., 2022). In Indonesia, the Long Form of the 2020 Population Census showed that persons with disabilities account for 1.43% of the total population (Badan Pusat Statistik, 2024). In the education sector, the national Basic Education Data (*Data Pokok Pendidikan*) recorded 245,350 students with special needs in the odd semester of the 2026/2027 academic year, or approximately 0.50% of all valid students (Kementerian Pendidikan Dasar dan Menengah, 2026). However, these data are not disaggregated by type of impairment, so the number of students with CP, or with physical and motor impairments more broadly, cannot be determined precisely. This data gap suggests that students with motor impairments remain relatively invisible in educational service planning, including in the development of learning media tailored to their needs.

In children with mild CP, who are generally classified at levels I–II of the Gross Motor Function Classification System (GMFCS; Palisano et al., 1997) and the Manual Ability Classification System (MACS; Eliasson et al., 2006), motor impairments often appear mild. Nevertheless, these impairments have a tangible impact on learning participation. Limitations in eye–hand coordination, fine motor control, and manipulative dexterity affect children's ability to write, use learning tools, and complete school tasks independently. Motor development is therefore not solely a clinical concern but also an integral part of special education services. This view is consistent with Law Number 8 of 2016 on Persons with Disabilities (Republik Indonesia, 2016) and Ministerial Regulation Number 48 of 2023 on reasonable accommodation for students with disabilities (Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, 2023).

Current evidence indicates that the most effective motor interventions for children with CP position the child as an active agent and train functional tasks in a specific and repetitive manner, namely task-specific and goal-directed training (Novak et al., 2020). This approach is grounded in the principle of experience-dependent neuroplasticity, which holds that changes in neural function are driven by training that is specific, repetitive, intensive, and salient to the individual (Kleim & Jones, 2008). The challenge is that high-intensity repetitive practice easily leads to boredom. In schools, such practice is also difficult to deliver consistently because of limited time, limited availability of therapists, and a lack of engaging media. This situation opens an opportunity for educational technology to provide practice media that are both motivating and theoretically grounded.

Virtual reality (VR) has been widely studied as a means of motor intervention for children with CP. Pereira et al. (2023) reviewed 14 studies and concluded that VR contributes to improved manual function in children with CP as an adjunct to conventional therapy. Kilcioglu et al. (2023) found that adding VR to conventional therapy yields significant short-term benefits for upper-limb function, although medium- to long-term effects were not significant. A meta-analysis by Xue et al. (2025) of 24 randomized controlled trials involving 850 children showed that VR-based motor games improved gross motor skills (MD = 1.67) and fine motor skills (SMD = 0.73), particularly when delivered more than four days per week for at least eight weeks. Maggio et al. (2024) reviewed 15 studies on immersive VR and reported benefits in both motor and cognitive domains. However, they also noted heterogeneity in devices and outcome measures, unclear

classification of immersion levels, generally small sample sizes, and an under-examined risk of cybersickness.

In Indonesia, the use of digital technology for children with physical and motor impairments is emerging, but its directions and targets remain diverse. Wicaksana et al. (2024) developed a VR game as a rehabilitation tool for persons with physical disabilities at a physiotherapy foundation; this initiative took place in a rehabilitation context, and the design of its motor tasks was not described in detail. Purwaningsih et al. (2025) applied VR in mathematics learning for students with physical disabilities in an inclusive school using a mixed-methods design with a control group and reported positive effects on students' mathematical understanding. That study, however, targeted academic achievement rather than motor development. Mawaddah et al. (2025) developed computer vision-based assistive technology that provides real-time visual feedback for fine motor training in children with CP. The technology was rated highly feasible by content experts, media experts, and practitioners, but it is non-immersive and has not yet been tested with users. Conversely, Prawesti et al. (2021) found that digital animation did not significantly improve self-care independence in children with CP ($p = 0.351$), suggesting that attractive digital media alone are insufficient without a structured motor practice design. A preliminary study by Ningsih et al. (2025) in special schools showed that children with mild CP responded positively to visual and interactive approaches and that teachers and parents were open to the use of VR. The same study identified barriers related to infrastructure, teacher readiness, and device availability, and it recommended developing VR media that are adaptive, practical, and contextual.

This review reveals three research gaps. First, international studies are dominated by clinical and rehabilitation settings that use commercial devices or games not designed on the basis of motor learning principles. Second, no VR medium specifically designed on task-specific motor learning principles for the motor development of children with CP in schools has been identified in Indonesia; existing studies focus on rehabilitation, academic achievement, or non-immersive technology. Third, the design process, that is, the translation of motor learning principles into task scenarios, difficulty grading, and feedback, together with testing with target users, is rarely reported transparently.

Building on a previous needs analysis (Ningsih et al., 2025), this study offers novelty in three respects. First, it explicitly maps task-specific motor learning principles, together with principles derived from experience-dependent neuroplasticity research, onto the design of a VR medium. These principles are operationalized in concrete media components, namely everyday functional tasks, repeatable task sequences, progressively sequenced task complexity, and immediate feedback, which distinguishes the approach from the use of generic commercial games. Second, it transparently reports the design and development process, from design and validation by experts in special education and instructional media to a limited trial with the target user. Third, the medium is developed as a learning medium for special schools rather than solely as a clinical therapy tool, so that it can be operated by special education teachers within motor development services.

Accordingly, this study addresses three research questions: (1) How is a VR learning medium based on task-specific motor learning designed to develop the motor skills of children with mild CP? (2) How feasible is the medium according to expert judgment? (3) How acceptable is the medium based on the performance of a child with mild CP in a limited trial? This article aims to describe the design and development of a VR learning medium based on task-specific motor learning for children with mild CP, to examine its feasibility through expert validation, and to examine its acceptability through a limited trial, as

a foundation for efficacy testing in subsequent research. The article reports the first design cycle of the medium.

METHODS OF RESEARCH

Research Design

This study employed a design-based research (DBR) approach. DBR emphasizes the development of learning solutions through cycles of design, limited implementation, and reflective evaluation in real-world contexts, with practitioners involved as partners (McKenney & Reeves, 2019; Wang & Hannafin, 2005). This approach was chosen because it enables researchers to develop media that are not only theoretically valid but also practical and applicable in special education settings. The procedure was designed to be iterative and to involve stakeholders (teachers, therapists, and children); this article reports its first design cycle. The operational procedure adapted the ADDIE model (Analysis, Design, Development, Implementation, Evaluation; Branch, 2009) and integrated it with the iterative principles of DBR. The study was conducted in six stages, as shown in Figure 1.

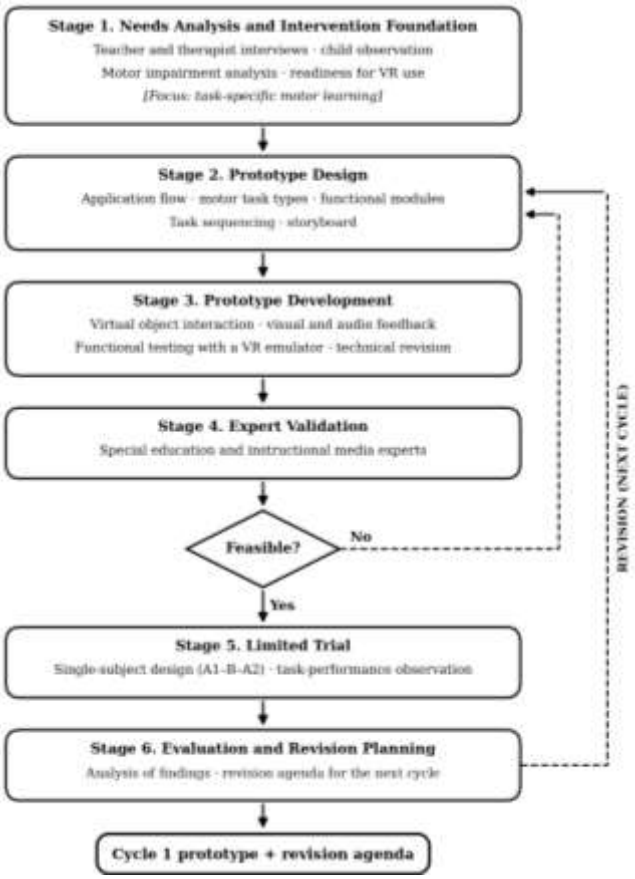

Figure 1. Research flow for developing a virtual reality medium based on task-specific motor learning using a design-based research approach adapted from the ADDIE model. The dashed lines show the planned revision paths; in the first cycle reported here, the expert validation path was not triggered, and the trial findings were carried forward to the next cycle
Source: *Adapted from Branch (2009) and McKenney & Reeves (2019)*

Each stage had distinct objectives, participants, instruments, and outputs, as summarized in Table 1. The stages were linked by two planned revision paths. If expert validation indicated that the product was not yet feasible, the prototype was to be returned to the design stage for revision, and problems identified during the limited trial were to serve as the basis for design revisions in the next cycle. In the cycle reported here, all four experts judged the prototype feasible for trial without revision, so the first path was not triggered. The prototype was also not modified after the limited trial; instead, Stage 6 consolidated the expert comments and trial findings into a documented revision agenda for the second cycle. Accordingly, this article reports a single design cycle, and the medium described in the results is the first-iteration prototype rather than a finalized product. This approach reflects the character of DBR, in which designs are refined progressively across cycles on the basis of data from real-world contexts (McKenney & Reeves, 2019).

Table 1. Activities, Participants, Instruments, and Outputs of Each Research Stage

Stage	Main Activities	Participants/Data Sources	Instruments	Outputs
1. Needs analysis and intervention foundation	Teacher and therapist interviews; child observation; analysis of motor impairments and readiness for VR use; determination of the task-specific motor learning focus	Special education teachers, therapists, and children with mild CP (Ningsih et al., 2025)	Interview guides, observation sheets	Needs profile and target motor skills
2. Prototype design	Development of the application flow, motor task types, functional practice modules, and difficulty grading	Research team	Matrix mapping task-specific motor learning principles to media components	Scenario design and media specifications
3. Prototype development	Programming of virtual object interactions and visual and audio feedback; functional testing with a VR emulator; initial technical revision	Research team and developer	Functional testing checklist	VR media prototype
4. Expert validation	Assessment of the feasibility of motor task content and the technical quality of the medium	Two special education experts and two instructional media/technology experts	Two expert validation sheets (17 items each)	Feasibility scores and expert comments
5. Limited trial	Use of the medium by the child in an A1–B–A2 design and observation of task performance	One child with mild CP (single subject)	Task-performance observation sheet (nine indicators)	Task-performance profile in phases A1, B, and A2
6. Evaluation and revision planning	Analysis of expert comments and trial findings; documentation of required design improvements	Research team	Revision notes	Revision agenda for the second design cycle

Source: Authors' research design, 2026

Participants and Setting

The study was conducted at YPAC Jakarta from July to September 2026. Participants were selected purposively according to the needs of each stage. Product validation involved four experts holding at least a master's degree: two special education experts (with expertise in children with physical and motor impairments and in adaptive media for children with special needs) and two experts in instructional media and technology.

The limited trial involved one child with mild CP who met the following inclusion criteria: (a) a diagnosis of CP from a medical professional; (b) GMFCS level I–II (Palisano et al., 1997) and MACS level I–II (Eliasson et al., 2006); (c) the ability to understand simple verbal instructions; (d) no history of uncontrolled epilepsy or severe visual impairment that would contraindicate the use of a VR headset; and (e) written permission from the parents. During the sessions, the child was accompanied by the researcher. The child's identity was anonymized using a code.

Instruments

Three types of instruments were used. First, interview guides and observation sheets were used in the needs analysis stage (Ningsih et al., 2025). Second, two expert validation sheets, each consisting of 17 items rated on a four-point scale (1 = very poor, 2 = poor, 3 = good, 4 = very good), were used. The special education validation sheet assessed five aspects: suitability for the characteristics of children with mild CP, alignment with task-specific motor learning principles, alignment with neuroplasticity principles, pedagogical and therapeutic aspects, and safety for the child. The media validation sheet assessed software engineering, visual and audio design, interaction and navigation, operational ease, and technical safety of use. Each sheet included space for comments and an overall feasibility conclusion.

Third, a task-performance observation sheet with nine indicators was used: target orientation, object identification, control direction, object selection, object transfer, object manipulation, action sequencing, task completion, and independent performance. Each indicator was scored 0 (unable), 1 (able with assistance), or 2 (able independently), yielding a total score ranging from 0 to 18.

Trial Design and Data Analysis

The limited trial used an A1–B–A2 single-subject design, consisting of a baseline phase before the intervention (A1), an intervention phase using the VR medium (B), and a second baseline phase after the intervention was withdrawn (A2) (Kazdin, 2021). In each phase, the child's performance was observed in one measurement session.

The content validity of the expert ratings was analyzed using Aiken's V index (Aiken, 1985), calculated with the following formula.

$$V = \Sigma s / [n(c - 1)] \quad (1)$$

In this formula, $s = r - lo$, where r is the score given by the expert, lo is the lowest score on the scale (1), n is the number of experts (two per instrument), and c is the number of rating categories (four). The V value was calculated for each item and then averaged for each aspect and for the instrument as a whole. V values were interpreted as high ($V > 0.8$), moderate ($0.4 \leq V \leq 0.8$), or low ($V < 0.4$) (Retnawati, 2016). Because each instrument was rated by two experts, V was used as a descriptive measure of expert agreement rather than as a test of statistical significance.

The trial observation data were analyzed descriptively by comparing indicator scores, total scores,

and mean scores across phases. The results are presented in a table and an indicator profile chart. Because each phase was represented by a single measurement session, the analyses of trend, stability, and data overlap commonly used in single-subject research were not performed. Accordingly, the trial data were used to describe the acceptability of the medium rather than to infer its efficacy, which is planned for a subsequent stage of research. Expert comments were analyzed qualitatively and descriptively to complement the quantitative data.

RESULTS AND DISCUSSION

Results

Needs Analysis

The needs analysis drew on the preliminary study by Ningsih et al. (2025) in special schools, which yielded three main findings. First, children with mild CP responded positively to visual and interactive learning approaches. Second, teachers and parents were open to the use of VR, but schools faced barriers related to infrastructure, teacher readiness, and device availability. Third, the study recommended developing VR media that are adaptive, practical, and contextual. These findings informed three design decisions: selecting a familiar everyday functional activity as the task context, presenting instructions visually and concretely, and using smartphone-based VR devices to make the medium more accessible to schools.

Design of the TANGKAS-VR Medium

The resulting first-iteration prototype, named TANGKAS-VR (*Tugas Aktivitas Nyata untuk Gerak dan Keterampilan Anak Spesifik berbasis Virtual Reality*, or Real Activity Tasks for Specific Movement and Skills of Children based on Virtual Reality), is a virtual kitchen simulation with the scenario *Siap Memasak?* ("Ready to Cook?"). In this scenario, the child plays the role of a cook who prepares soup step by step through a single functional task sequence. The medium runs on a smartphone mounted in a VR headset type VR box with a stereoscopic display. The child directs a pointer (reticle) toward virtual objects to select and interact with them and moves within the kitchen through red circular markers (teleport points) without having to walk physically.

The task sequence consists of five activities: (1) selecting ingredients, namely tomatoes and carrots; (2) turning on the stove; (3) cooking and stirring the soup; (4) disposing of waste in a pedal bin; and (5) serving the soup in a bowl (Figure 2). Each activity is preceded by a model video showing real hands performing the target movement, such as grasping a tomato, pressing the stove button, and stirring the food. Successful task completion is followed by immediate feedback in the form of a thumbs-up animation, confetti, reinforcing text such as *Kompor Menyala!* ("The stove is on!"), sparkle effects, and sound. In the demonstration video, the complete task sequence could be finished in approximately five minutes.

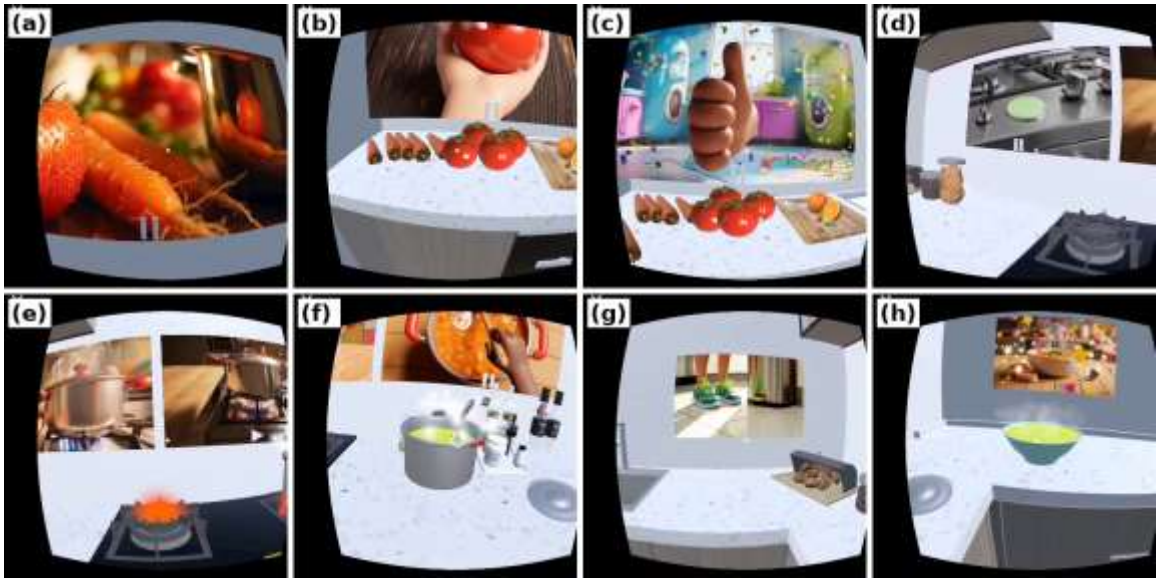

Figure 2. Screens of the TANGKAS-VR medium with the scenario *Siap Memasak?* ("Ready to Cook?"): (a) opening video; (b) video instruction for grasping a tomato, with ingredients on the counter; (c) thumbs-up and confetti feedback after successful task completion; (d) instruction for pressing the stove button; (e) stove turned on; (f) stirring soup in a pot; (g) instruction for disposing of waste using a pedal bin; (h) serving soup in a bowl
Source: *Screenshots of the TANGKAS-VR application, 2026*

The intended translation of task-specific motor learning principles, and of principles derived from neuroplasticity research, into media components is summarized in Table 2. The mapping documents the design rationale of each feature; it describes how the principles were intended to be operationalized and should not be read as evidence that the corresponding mechanisms, such as neuroplastic change, occurred. Some principles were only partially implemented in this first prototype: task complexity follows a fixed sequence rather than adjustable difficulty levels, and safety relies on design features rather than on measured outcomes.

Table 2. Mapping of Motor Learning Principles to Intended Design Features of the Tangkas-VR Medium

Principle	Theoretical Basis	Implementation in the Medium
Task-specific and functional practice	Novak et al. (2020); Kleim & Jones (2008)	Movements are practiced within an everyday activity (cooking soup): selecting, pressing, stirring, disposing, and serving
Goal-directed practice	Novak et al. (2020)	Each activity has a clear goal and leads to a meaningful end product, namely a served bowl of soup
Movement demonstration	Schmidt et al. (2019)	A model video of real hands is shown before each activity
Progressive task sequencing (partially implemented)	Schmidt et al. (2019)	Activities follow a fixed order from simple actions (selecting a single object) to multistep sequences (cooking and serving); difficulty cannot yet be adjusted to individual ability
Repetition	Kleim & Jones (2008)	The task sequence can be replayed within a single practice session
Immediate feedback	Schmidt et al. (2019)	Thumbs-up animation, confetti, reinforcing text, and sound effects after successful completion

Principle	Theoretical Basis	Implementation in the Medium
Engagement (salience)	Kleim & Jones (2008)	A familiar cooking theme, bright visuals, and a narrative flow that sustains the child's motivation
Safety-oriented design	Maggio et al. (2024)	Movement via teleportation without physical walking and a short duration for each task sequence (approximately five minutes); discomfort and cybersickness were not yet measured

Source: Authors' design, 2026

Expert Validation

The results of validation by the four experts are presented in Table 3. The total scores given by the two special education experts were 62 and 63, and those given by the two media experts were 62 and 60, out of a maximum score of 68.

Table 3. Expert Validation Results Based on Aiken's V

Aspect	Items	Mean Score	Aiken's V	Category
Special education instrument				
Suitability for the characteristics of children with mild CP	4	3.63	0.88	High
Alignment with task-specific motor learning principles	4	3.75	0.92	High
Alignment with neuroplasticity principles	3	3.67	0.89	High
Pedagogical and therapeutic aspects	2	3.50	0.83	High
Safety for the child	4	3.75	0.92	High
Overall	**17**	**3.68**	**0.89**	**High**
Media instrument				
Software engineering	4	3.75	0.92	High
Visual and audio design	4	3.63	0.88	High
Interaction and navigation	3	3.83	0.94	High
Operational ease	3	3.33	0.78	Moderate
Technical safety of use	3	3.33	0.78	Moderate
Overall	**17**	**3.59**	**0.86**	**High**

Source: Expert validation data, 2026

At the instrument level, both instruments yielded *V* values in the high category: 0.89 for the special education instrument and 0.86 for the media instrument. On the special education instrument, all aspects fell into the high category (0.83–0.92), with the highest values for alignment with task-specific motor learning principles and safety for the child (0.92). On the media instrument, interaction and navigation obtained the highest value (0.94), whereas operational ease and technical safety of use fell into the moderate category (0.78). These values reflect the experts' judgments of the design and do not directly measure motor learning, neuroplastic change, or safety in use.

At the item level, no item received a score below 3 (good). Eleven of the 17 items on the special education instrument and 9 of the 17 items on the media instrument obtained $V = 1.00$, meaning that both experts gave a score of 4. The items with the lowest *V* (0.67) were those rated 3 by both experts. On the special education instrument, these items concerned adjusting task difficulty to individual ability, the adequacy of movement repetition, task variation, support for monitoring motor progress, and a rest or pause mechanism. On the media instrument, they concerned application response time, the timeliness of feedback, ease of operation and configuration by teachers, headset ergonomics, and potential lag that could trigger motion sickness.

The experts' qualitative comments were consistent with the quantitative data. The special education experts judged that the motor activities in the medium were relevant to the child's functional abilities, applied task-specific motor learning principles systematically, and could be used by teachers and therapists as a supporting intervention tool. The media experts judged that the application ran stably, had clear visuals and a logical activity flow, and offered responsive interaction. All four experts concluded that the medium was feasible for trial without revision. Therefore, the revision loop to the design stage was not triggered, and the items with the lowest *V* values were documented in the revision agenda for the next design cycle.

Limited Trial

The results of observing the child's performance in phases A1, B, and A2 are presented in Table 4 and Figure 3. The total score increased from 2 (11.1%) in phase A1 to 14 (77.8%) in phase B and then to 16 (88.9%) in phase A2. The mean indicator scores were 0.22, 1.56, and 1.78, respectively, on a 0–2 scale.

Table 4. Task-Performance Scores of the Child in Each Phase

No.	Indicator	A1	B	A2
1	Target orientation	1	2	2
2	Object identification	1	2	2
3	Control direction	0	2	2
4	Object selection	0	2	2
5	Object transfer	0	2	2
6	Object manipulation	0	1	2
7	Action sequencing	0	1	2
8	Task completion	0	1	1
9	Independent performance	0	1	1
Total score (maximum 18)		**2**	14	**16**
Mean indicator score		0.22	1.56	1.78
Percentage of maximum score		11.1%	77.8%	88.9%

Source: Limited trial data, 2026

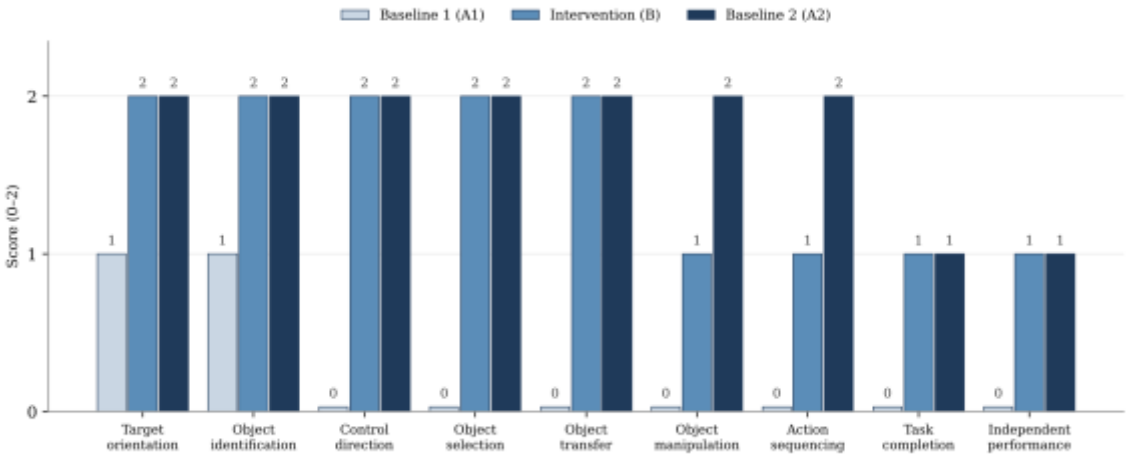

Figure 3. Profile of the nine task-performance indicators across phases A1, B, and A2. The chart compares indicator profiles between phases and is not a time-series graph
Source: *Limited trial data, 2026*

The changes can be grouped into four patterns. Target orientation and object identification increased from 1 to 2 in phase B and were maintained in phase A2. Control direction, object selection, and object transfer showed the largest increase, from 0 to 2 in phase B, and were maintained in phase A2. Object manipulation and action sequencing increased from 0 to 1 in phase B and rose further to 2 in phase A2. Task completion and independent performance increased from 0 to 1 in phase B and remained at 1 in phase A2.

Discussion

The first finding of this study is that task-specific motor learning principles can be translated into a VR medium through a single, coherent functional activity scenario rather than through isolated movements, as is common in commercial games. Novak et al. (2020) emphasized that the most effective motor interventions for children with CP involve practicing real tasks that are specific and goal-directed. The soup-cooking scenario meets these criteria because every movement, such as selecting ingredients, pressing the stove button, and stirring, has a clear and meaningful goal for the child. The design also draws on the principles of specificity, repetition, and salience that, according to Kleim and Jones (2008), are associated with experience-dependent neuroplasticity, although neural change was not measured in this study. The model videos preceding each activity and the immediate feedback following successful completion are consistent with motor learning principles regarding the importance of demonstration and knowledge of results (Schmidt et al., 2019). Such integration responds to the concern raised by Maggio et al. (2024) about the heterogeneity and unclear design rationale of VR media used in previous studies. The medium also differs from those previously developed in Indonesia, which are non-immersive (Mawaddah et al., 2025), focused on academic achievement (Purwaningsih et al., 2025), or situated in a rehabilitation context (Wicaksana et al., 2024).

The validation results indicate that the medium is feasible in terms of both content and technical quality. The highest values for alignment with task-specific motor learning principles and for safety for the child suggest that the experts recognized the theoretical rationale and the safety-oriented features of the design. However, these ratings are expert judgments; they do not demonstrate safety in use, which requires systematic monitoring of discomfort and cybersickness across repeated sessions (Kennedy et al., 1993). Conversely, the lower values for operational ease and technical safety indicate that the main challenge of the medium lies in its implementation in schools rather than in its content. This finding is consistent with the barriers related to teacher readiness and device availability identified by Ningsih et al. (2025), as well as with the observation by Maggio et al. (2024) that the risk of cybersickness remains under-examined. The items concerning individual difficulty adjustment and the adequacy of repetition also received lower values. This suggests that the medium still follows a single scenario for all children and is therefore not yet fully adaptive, as recommended in the needs analysis; its graded character is currently limited to a fixed progression of task complexity. It should be noted that a *V* value of 0.67 on a four-category scale with two raters means that both experts rated the item as “good”, not that the item was rated negatively.

The limited trial results show a pattern that can be explained through the stages of motor learning. The largest increase in phase B occurred in control direction, object selection, and object transfer, indicators associated with mastering how to interact within the virtual environment. This pattern reflects a transition from the cognitive stage, in which the child is still understanding how the task works, to the associative stage, in which movements become more consistent (Schmidt et al., 2019). Object manipulation and action

sequencing reached the maximum score only in phase A2, suggesting that skills requiring the coordination of several steps need longer exposure to consolidate. Meanwhile, task completion and independent performance remained at a score of 1 at the end of the trial. Completing the entire sequence independently is the most demanding requirement of the scenario, so it is reasonable that the child still needed assistance. This finding is consistent with the meta-analysis by Xue et al. (2025), which showed that the benefits of VR training appear mainly when it is delivered more than four days per week for at least eight weeks, a considerably longer period than that of this trial.

The fact that scores in phase A2 did not return to the A1 level may indicate that performance was maintained after the intervention was withdrawn. However, this finding should be interpreted with caution. Each phase was represented by only one measurement session, so trend, stability, and maintenance of performance could not be assessed as required in single-subject designs (Kazdin, 2021). The increase in scores may also reflect the child's growing familiarity with the virtual environment. Moreover, the observed indicators measure performance on virtual tasks. Levac et al. (2019) explained that skills learned in VR do not automatically transfer to real-world movements, so improved performance in VR cannot yet be equated with improved motor function in daily activities. Neuroplasticity was also not measured directly in this study. Thus, the trial results are best interpreted as preliminary evidence that the medium is acceptable and usable for a child with mild CP, providing a basis for more rigorous efficacy testing.

CONCLUSION

This study produced the first-iteration prototype of TANGKAS-VR, a VR learning medium based on task-specific motor learning for children with mild CP, in the form of a virtual kitchen simulation with the scenario *Siap Memasak?* ("Ready to Cook?"). The medium translates motor learning principles into a sequence of functional cooking tasks supported by model videos, progressively sequenced tasks, and immediate feedback. Validation by four experts showed that the medium is feasible, with high Aiken's V values from the special education experts (0.89) and the media experts (0.86). A limited trial with one child with mild CP showed an increase in task-performance scores from phase A1 to phases B and A2. The largest gains occurred in skills related to interacting with virtual objects, whereas task completion and independence still required assistance. These findings indicate that the medium is acceptable and usable for children with mild CP but do not yet constitute evidence of intervention efficacy, safety in use, or neuroplastic change.

In the next design cycle, it is recommended to add adjustable difficulty levels tailored to each child's ability, a pause feature, progress records that teachers can monitor, and simpler configuration guidance for teachers. Headset ergonomics and potential lag also require attention, and discomfort and cybersickness should be monitored systematically, for example using the Simulator Sickness Questionnaire (Kennedy et al., 1993), to provide empirical evidence of safety. For future research, the efficacy of the medium should be tested with a larger number of participants, a design with repeated measurements in each phase (e.g., a multiple-baseline design), a longer intervention period, and measures of motor function in real-world activities to assess skill transfer. The practicality of the medium from the perspective of teachers and therapists should also be evaluated systematically.

This study has several limitations. It reports only one design cycle: the prototype was not revised after expert validation or after the limited trial, so the planned revisions have not yet been implemented or

tested. The trial involved only one child, with one measurement session per phase, so the results cannot be generalized and cannot be used to infer causality. Validation was conducted by two experts per instrument and did not involve clinical therapists. In addition, the performance indicators measured performance on virtual tasks rather than physical motor ability directly, and claims regarding safety and alignment with neuroplasticity principles are limited to design rationale and expert judgment.

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AUTHOR CONTRIBUTIONS

Kholifatul Novita Ningsih contributed to the conceptualization of the study, development of the research methodology, design of the medium, data analysis, and preparation of the initial manuscript. Trisna Mulyeni and Neddyana Pahlawaty contributed to the needs analysis, development of the research instruments, and interpretation of the findings. Wahyu Hardiani and Citra Ashri Maulidina contributed to data collection during the limited trial and to data processing. Hendriano Meggy contributed to the development of the TANGKAS-VR application and its technical testing. Alyana Nur Fadillah and Khalda Azizah contributed to content development, documentation, and editing of the manuscript. All authors participated in the discussion of the research findings, reviewed and approved the final version of the manuscript, and are responsible for the integrity and accuracy of the work.

CONFLICT OF INTEREST

The authors declare that there are no financial or non-financial conflicts of interest that could have influenced the conduct of the research, data analysis, preparation, or publication of this article.

ARTIFICIAL INTELLIGENCE (AI) USE STATEMENT

In preparing this article, the authors used artificial intelligence (AI) technology as an assisting tool for language editing, grammar checking, and improving the structure and clarity of the manuscript. AI was not used to generate, manipulate, or analyze the research data. The authors retain full responsibility for the content of the article, interpretation of the findings, accuracy, and integrity of the manuscript.

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