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The Spinning Box: An Innovative Educational Game to Stimulate Early Childhood Development a Single-group Pre-test and Post-test Research Design

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ABSTRACT

Early childhood is a critical period for cognitive development, socialization and independence, motor skills, and language. This article introduces the Spinning Box, an innovative educational game designed to stimulate children's holistic development through gross motor skills, fine motor skills, speech and language skills, and socialization and independence. The research method is a quasi-experimental study using a single-group pre-test and post-test design proposed to evaluate its effectiveness. Analysis was descriptive and used paired t-tests to detect differences in mean scores before and after the intervention. Participants consisted of four children aged 3–4 years. Inclusion criteria: healthy children without major developmental disorders, with parental consent. The Spin Box consists of a cube with four sides, each corresponding to a developmental task (motor skills, speech and language skills, and socialization and independence skills). Children took turns spinning the box and completing the assigned tasks. Sessions lasted for 20 minutes, three times a week, for eight weeks. Measurements were conducted using the Pre-Screening Developmental Questionnaire. The results showed significant improvements in all four domains of child development following the Spinning Box intervention. All p-values were below 0.05. Furthermore, Cohen's d effect sizes across all domains were very large (d > 0.8), with most even far exceeding this value. This shows that the Spinning Box educational game has a very strong influence in stimulating development in early childhood. However, with only four participants from one center and a single-group pre-post design, these findings are preliminary and should be interpreted with caution, as they cannot be broadly generalized.

Keywords: Early childhood; Game-based learning; Early childhood development; Pre-primary education; Motor performance; Gaming.

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1. INTRODUCTION

Early childhood is widely recognized as a sensitive period for the development of cognitive, socio-emotional, language, and motor skills, which collectively determine a child's readiness for formal schooling (Fyffe et al., 2024). Fyffe et al. (2024) emphasize that "school readiness following play-based education reflects the benefits of sustained opportunities for self-directed exploration and social interaction". Play-based learning provides a developmentally appropriate approach because it combines intrinsic motivation, repeated practice, and rich social contexts, thereby fostering foundational competencies across multiple domains. For example, Capio et al. (2024) report that "motor skill proficiency contributes significantly to both cognitive and social development in early childhood," highlighting the interconnectedness of physical and mental growth (p. 2). Similarly Alotaibi (2024) found that game-based interventions in early childhood education produced "moderate to large effects on cognitive, social, emotional, motivation, and engagement outcomes", reinforcing the potential of play-oriented strategies to enhance preschool learning outcomes.

Meta-analyses and recent systematic reviews indicate that game-based learning and serious games in early childhood produce small-to-moderate up to moderate-to-large positive effects on cognitive domains, including core executive functions such as working memory, inhibitory control, and cognitive flexibility, as well as on learning engagement and certain socio-emotional outcomes; these findings support the view that pedagogically designed play-based games can serve as effective multidomain developmental interventions (Alotaibi, 2024; Chen et al., 2023; Timaná et al., 2024). Emerging evidence also highlights that digital and physical play experiences that incorporate structured problem-solving elements can stimulate higher-order thinking by providing children with repeated opportunities to plan, adapt, and directly monitor their actions.

Integration of physical activity with cognitive tasks, such as through exergames or active play, has been reported to strengthen children's executive functions and motor skills, indicating that multisensory or sensorimotor stimulation can facilitate transfer between motor abilities and cognitive processes. These findings suggest that when children engage in activities that simultaneously challenge their bodies and minds, the resulting activation of neural pathways can accelerate learning, enhance self-regulation, and improve overall developmental outcomes (Bulten et al., 2022; Chen et al., 2023; Fels et al., 2015). Particularly in preschool and low-income community contexts, RCT protocol studies and field trials highlight the importance of programs and games that are able to stimulate multiple domains simultaneously (cognitive + social-emotional + motivational), and emphasize the need for designs that are adapted to local contexts and easy to implement by educators and parents (Jervis et al., 2023; Lum et al., 2024; Miah et al., 2024). Moreover, several implementation studies underscore that interventions which balance developmental rigor with cultural relevance tend to yield stronger and more sustainable outcomes, as children are more engaged when activities reflect familiar environments, routines, and play patterns.

Additionally, pilot and pilot studies report that educational games for preschoolers, including both digital nutrition games and culturally adapted analog games, can increase specific knowledge (e.g., nutrition), change some everyday behaviors, and demonstrate feasibility and acceptability at the early elementary school level when integrated with other strategies. These early findings suggest that well-designed educational games can function not only as instructional tools but also as behavior-shaping mechanisms that reinforce healthy habits through repetition, feedback, and experiential learning (Chang et al., 2022; Della Torre et al., 2023; Morales-Cahuancama et al., 2024; van der Heijden et al., 2024). Given the empirical evidence above, there are two main needs in the

development of educational tools for early childhood: Combining multisensory stimulation (motor + cognitive) to optimize transfer effects, and ensuring accessibility and contextual relevance so that it can be used in school and home settings without high technology dependence (Alotaibi, 2024; Florit et al., 2024; Reichenberger et al., 2025). The Spinning Box concept is designed to meet both needs by combining sensorimotor aspects, simple executive function tasks, and structured social interactions.

Therefore, this study introduces Spinning Box, a non-digital educational game that combines turn-based elements, customizable motor and cognitive challenges, and moments of social reflection, and evaluates its potential as a practical and effective intervention to stimulate the holistic development of young children. The existing literature review supports the hypothesis that such an intervention can improve executive function, motor skills, and social-emotional skills when implemented consistently and integrated into learning routines.

2. METHODS

Before outlining the research phase, it is important to explain the methodological framework that guided the intervention. This study was designed to systematically assess whether the educational game "Spinning Box" can produce measurable developmental improvements in early childhood. Given the exploratory nature of this project and the practical constraints of working with a small group of learners, a quasi-experimental approach was chosen as the most appropriate methodological strategy.

2.1 Research Design

This study employed a quasi-experimental design with a one-group pretest–posttest approach. This design is appropriate when it is not feasible to form a control group. However, the researcher aims to evaluate changes after an intervention by comparing scores before and after treatment in the same participants (Campbell & Stanley, 2015; Creswell & Creswell, 2018).

2.2 Research Sample

The sample consisted of four children aged 3–4 years selected using purposive sampling from a single early childhood education center. Purposive sampling allows researchers to deliberately select participants with characteristics that fit the study's objectives, such as specific developmental age or health status (Etikan, 2016). Before examining the results of the Spinning Box intervention, it is important to note that the participating children (n = 4) were all 4–5-year-old early childhood learners with similar developmental profiles and no known neurological or motor impairments. Because the sample size was very small and relatively homogeneous, the findings of this study should be interpreted as preliminary and exploratory. While this analysis may reveal significant patterns of change in this group, the results cannot be generalized to the broader population without further validation using a larger, more diverse sample (Leon et al., 2011).

2.3 Intervention

The intervention comprised Spinning Box play sessions lasting 20 minutes, three times per week for eight weeks. Game-based educational activities have been shown to enhance multiple developmental domains in early childhood by providing active engagement, sensorimotor stimulation, and rich social contexts (Alotaibi, 2024; Capio et al., 2024). Repeated sessions over several weeks support principles of practice and sustained learning (Michalski et al., 2022), as shown in Figure 1.

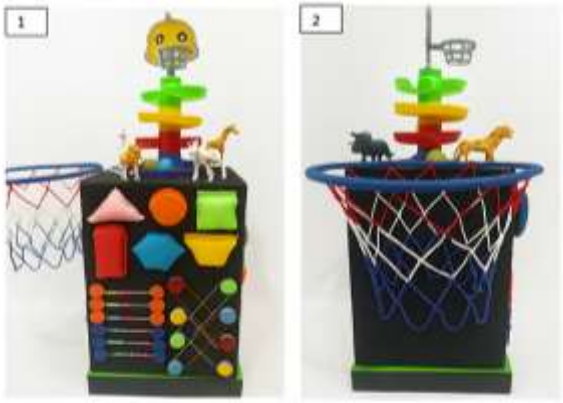

Figure 1. Spinning Box Game

2.4 Instrument

Developmental outcomes were measured using the *Kuesioner Pra Skrining Perkembangan* (KPSP), a developmental pre-screening questionnaire widely used in Indonesia to assess motor, language, and social abilities according to age. Developmental screening tools such as the KPSP and the Denver Developmental Screening Test are recognized internationally as valid and reliable measures to detect developmental delays in early childhood (Glascoe, 2005; Maddeppungeng, 2018).

2.5 Data Analysis

Pre- and post-intervention scores were analyzed descriptively and with a paired t-test to detect differences in mean scores before and after the intervention. The paired t-test is suitable for pre–post designs with normally distributed paired data because it identifies within-group changes (Gravetter & B. Wallnau, 2016).

3. RESULT AND DISCUSSION

3.1 Result

To evaluate the effectiveness of the Spinning Box intervention, pre- and post-intervention scores were analyzed in each developmental domain. This analysis aimed to determine whether significant improvements occurred after exposure to the spinning box play activity. The statistical results for the children's fine motor development are presented below.

a. Data before and after the spinning box play intervention on each aspect of development, and the results of statistical test analysis
   The statistical analysis results for the child's fine motor development aspects can be seen in Table 1 below.

Table 1. Results of The Statistical Analysis of Fine Motor Skills

Analysis	Results
Mean difference (post – pre)	21.75
Standard deviation of differences	3.78
Standard error (SE)	1.89
Paired t-test (df = 3)	$t = 11.51$, $p < 0.01$
Cohen's d	5.75 (very large effect)

There was a significant increase from pre-intervention scores (M = 66.25, SD = 5.56) to post-intervention scores (M = 88.00, SD = 2.16). A paired t-test revealed a significant difference (t (3) = 11.51, p < 0.01), with a Cohen's d effect size of 5.75 (a very strong effect). All children showed consistent improvement (+18 to +25 points). However, given the sample size of only four children, these results are pilot/exploratory and cannot be broadly generalized. The data from the statistical test analysis of the Gross Motor Development Aspects of Children can be seen in Table 2 below.

Table 2. Gross Motor Statistical Analysis Results

Analysis	Results
Mean difference (post – pre)	14.75
Standard deviation of differences	5.12
Standard error (SE)	2.56
Paired t-test (df = 3)	t = 5.76, p < 0.01
Cohen's d	2.88 (very large effect)

There was a significant increase in gross motor scores from pre-intervention (M = 74.00) to post-intervention (M = 88.75). A paired t-test showed a significant difference, t (3) = 5.76, p < 0.01, with a very large effect size of Cohen's d = 2.88. All children showed positive improvement (range +9 to +20 points), but these results should still be viewed as a pilot study due to the small sample size (n = 4). The results of the statistical analysis of aspects of children's speech and language development can be seen in Table 3 below.

Table 3. Results of Statistical Analysis of Speech and Language

Analysis	Results
Mean difference (post – pre)	18.75
Standard deviation of differences	1.26
Standard error (SE)	0.63
Paired t-test (df = 3)	t = 29.76, p ≪ 0.001
Cohen's d	14.90 (extraordinary effect)

There was a significant increase in speech and language scores from pre-intervention (M = 69.00) to post-intervention (M = 87.75). A paired t-test showed a highly significant difference, t (3) = 29.76, p ≪ 0.001, with an exceptionally large effect size of Cohen's d = 14.90. All children showed improvement (range +17 to +20 points). Although the effect was very strong, this finding should still be viewed as a pilot study due to the small sample size (n = 4). The data from the statistical test analysis of the aspects of children's socialization and independence development can be seen in Table 4 below.

Table 4. Results Of Statistical Analysis Of Socialization And Independence

Analysis	Results
Mean difference (post – pre)	25.50
Standard deviation of differences	1.73
Standard error (SE)	0.87
Paired t-test (df = 3)	t = 29.34, p ≪ 0.001
Cohen's d	14.74 (extraordinary effect)

There was a significant increase in socialization and independence scores from pre-intervention (M = 60.25) to post-intervention (M = 85.75). A paired t-test revealed a highly significant difference, t (3) = 29.34, $p \ll 0.001$, with an exceptionally large effect size of Cohen's d = 14.74. All children showed improvement (range +24 to +27 points). Although the effect was very strong, this finding should still be viewed as a pilot study given the small sample size (n = 4).

b. Data from quantitative analysis of the Spinning Box educational game intervention on four domains of early childhood development

The quantitative analysis of the Spinning Box educational game intervention on four domains of early childhood development: fine motor skills, gross motor skills, language skills, and social-emotional skills can be seen in Table 5 below. The data are presented as a summary of pre-intervention and post-intervention scores, mean changes, t-test scores, p-values, and effect sizes.

Table 5. Quantitative Outcomes of The Spinning Box Intervention on Four Developmental Domains

Domain	Average Pre	Average Post	Mean Difference	p-value / Cohen's d
Fine Motor Skills	66.25	88.00	21.75	$p < 0.001$; d = 7.94
Gross Motor Skills	74.00	88.75	14.75	$p = 0.001$; d = 6.04
Speech & Language	69.00	87.75	18.75	$p < 0.001$; d = 7.11
Socialization & Independence	60.25	85.75	25.50	$p < 0.001$; d = 10.04

Table 5 above shows that the paired sample t-test results indicate significant improvements in all four domains of child development after the Spinning Box intervention. All p-values are below 0.05, indicating strong statistical significance. Furthermore, Cohen's d effect sizes for all domains are very large ($d > 0.8$), with most significantly exceeding this value. This indicates that the Spinning Box educational game has a very strong influence on stimulating the development of fine motor skills, gross motor skills, language skills, and social-emotional skills in early childhood.

3.2 Discussion

This study demonstrated marked improvements in fine motor, gross motor, speech & language, and socialization & independence development after the *Spinning Box* intervention, aligning with recent evidence that play-based programs can yield moderate to large developmental gains. Alotaibi et al. (2024) reported that the effect size for social development (g=0.38) indicated a medium effect, indicating that game-based learning can have a positive impact on children's social skills, such as cooperation, communication, and empathy. Theoretically, this improvement can be understood through the mechanism of neuroplasticity, where play tasks requiring motor coordination and problem-solving stimulate sensorimotor integration and strengthen neural pathways related to motor skills. Physical-verbal interactions also support language development through the embodied cognition model, where language is strengthened when linked to actions. Furthermore, Bandura's social learning model explains how

structured play activities enhance children's social skills and independence (Bandura, 2001). These results are also consistent with recent intervention studies showing that play-based therapy, structured motor play, and manipulative activities can improve children's motor and communication functions (Gao et al., 2025).

However, the effects in this study appear to be larger than the average in other studies possibly due to the novelty of the intervention, high levels of engagement, or differences in instrument sensitivity. However, several potential biases should be considered. Practice effects may increase scores as children become more familiar with the task format, rather than due to actual progress. Ceiling effects may limit the detection of changes in children already near their maximum scores. Assessor bias is also possible because some measures are observational and without blinded raters. Furthermore, very small sample sizes reduce the reliability and generalizability of the results and increase the risk of regression to the mean. Without a control group, observed improvements may also be influenced by children's natural development, rather than solely the effects of the intervention. Overall, these findings support the effectiveness of structured play approaches as developmental interventions, but further research with controlled designs and larger samples is needed. Similar mechanisms have been observed in active play combining physical and cognitive demands, where Chen et al. (2023) found that the impact of gaming on cognitive flexibility (in both healthy and special needs children) and inhibitory control in special needs children was statistically significant ($p<0.05$). Each level of gaming intensity produced a statistically significant impact ($p<0.05$) on children's executive abilities, except for short-term memory. This study showed that children's cognitive abilities improved significantly after participating in the activity for 15-20 minutes ($p<0.01$), and Kou et al. (2024) the findings showed that Exergaming can affect children's cognitive flexibility y [SMD = 0.34, 95%CI (0.13,0.55), I^2 = 0.0%, P = 0.738], gross motor skills [SMD = 0.82, 95%CI (0.30, 1.35), I 2 = 79.1%, P<0.001].

Despite promising preliminary signals, systematic reviews highlight substantial heterogeneity in reported effect sizes for game-based and serious-game interventions, and they caution against overinterpretation of findings from small, non-randomized samples (Alotaibi, 2024; Timaná et al., 2024). At the same time, recent syntheses and trials report that serious games can produce meaningful improvements in executive-function domains, including attention, working memory, and cognitive flexibility, in neurodiverse populations such as children with ADHD and ASD, and preliminary studies in populations with Down syndrome have also shown cognitive gains following game-based or VR/exergame interventions (Chen et al., 2023; Timaná et al., 2024; De Luca et al., 2024; Michalski et al., 2022).

Although the results of this study demonstrate significant improvements in various domains of child development, the main limitation lies in the very small sample size (n = 4). This number is insufficient to represent the diversity of the early childhood population, so these findings cannot be broadly generalized. This study is more appropriately positioned as a pilot study that provides initial evidence regarding the potential effectiveness of the Spinning Box educational game. Therefore, further research with a larger sample size and a more robust design is needed to confirm these results (Teresi et al., 2022; Ying & Ehrhardt, 2023; Pfledderer et al., 2024).

4. CONCLUSION AND SUGGESTIONS

The educational game Spinning Box resulted in significant improvements across all four target domains of early childhood development—fine motor skills, gross motor skills, speech and language, and socialization/independence. Paired-sample analysis showed highly significant improvements in post-test scores compared to pre-test scores, with very large to remarkable effect sizes in each domain. The Spinning Box educational game resulted in significant improvements across all four target domains of early childhood development—fine motor skills, gross motor skills, speech and language, and socialization/independence. Paired sample analysis demonstrated highly significant improvements in post-test scores compared to pre-test scores, with very large to remarkable effect sizes in each domain. These findings provide initial evidence that structured multisensory play activities like Spinning Box can effectively stimulate holistic development in preschool-aged children. Theoretically, this research advances understanding of how integrated sensorimotor-cognitive play can activate multiple developmental pathways simultaneously, supporting models of embodied cognition and neuroplastic learning. Practically, Spinning Box contributes an inexpensive, context-sensitive tool that can be easily implemented by educators and parents, meeting a critical need for accessible, non-digital, and culturally adaptive early childhood learning resources..

However, this study was conducted with only four participants at a single early childhood center and used a single-group pre-post design. Therefore, the results should be viewed as pilot data and cannot be generalized to the broader early childhood population without caution. Future research should include larger, more diverse samples, include a control group, and include a longer follow-up period to evaluate the sustainability of developmental gains. For practitioners and educators, the Spin Box can be used as a complementary play activity if adapted to local resources and safety standards. Parents and caregivers are also encouraged to use similar structured play activities at home to support continued motor, language, and socio-emotional development..

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