JPII 14 (3) (2025) 509-521

Jurnal Pendidikan IPA Indonesia

https://journal.unnes.ac.id/journals/jpii

# INTEGRATION OF BENTENGAN TRADITIONAL GAMES IN SCIENCE LEARNING TO IMPROVE PRESCHOOL CHILDREN'S COGNITIVE AND MOTOR DEVELOPMENT

**D. A. Sari*[1], W. M. Mapunda[2], R. P. Bayan[3], A. Asyhari[4]**

[1]Faculty of Education Science, Universitas Muhammadiyah Jakarta, Indonesia
[2]Founder And CEO, Academic Solutions Network (ASONE), Dar Es Salaam, Tanzania
[3]Institute of Education, City College of Calapan, Oriental Mindoro, Philippines
[4]Physics Education, Universitas Islam Negeri Raden Intan Lampung, Lampung, Indonesia

**DOI: 10.15294/jpii.v14i3.29894**

Accepted: July 9th, 2025. Approved: September 14th, 2025. Published: September 15th 2025

**ABSTRACT**

This study confirms that the traditional game Bentengan can serve as a contextual model for early childhood science learning, effectively integrating cognitive, motor, and social-emotional development. Empirical evidence suggests that embodied interaction during play enhances preschoolers' conceptual understanding of force, motion, balance, and environmental phenomena, while also strengthening their gross and fine motor coordination. Theoretically, these findings contribute to embodied cognition studies by demonstrating how sensorimotor engagement functions as a foundation for abstract scientific reasoning in STEM domains. Practically, the integration of culturally grounded games provides a locally relevant and engaging alternative to conventional instruction, positioning Bentengan as a sustainable approach for culture-based preschool education that aligns with current curriculum reforms and the broader agenda of inclusive, active, and meaningful early science education.



Keywords: science learning; preschool education; cognitive development; motor skills

## INTRODUCTION

The integration of traditional games into early childhood education is gaining attention as an innovative approach to promote cognitive, motor, and social development (Bazaz et al., 2018; Sutapa et al., 2021; Ayaz-Alkaya & Akca, 2025). This pedagogical approach aligns with the global educational agenda (Reimers, 2024), particularly with Sustainable Development Goals (SDGs) 4 and 3, which aim to ensure inclusive and equitable quality education and promote well-being for all ages. As global childhood development initiatives emphasize holistic learning, traditional play provides culturally grounded and developmentally appropriate pathways to foster essential 21st-century competencies. However, Bianconi et al. (2024) report that the increasing dominance of screen-based entertainment and academic formalization in the early years has led to the marginalization of traditional play, resulting in reduced physical activity and weakened socio-emotional engagement in children. This concerning global trend requires deeper educational attention. Despite these challenges, the research gap persists: the role of traditional strategic games in preschool science learning remains underexplored, particularly in integrating conceptual understanding with motor development.

Game-based learning, especially in preschools, has been widely recognized for its ability to enhance conceptual understanding, prob-

***Correspondence Address**
E-mail: diah.andika@umj.ac.id

lem-solving skills, and collaborative learning experiences (Carulla et al., 2021; Aslan et al., 2022; Devi, 2022). However, although structured and digital game-based approaches have been extensively studied, few empirical studies focus on how traditional games can simultaneously strengthen science learning and motor coordination. Recent international research underscores this gap. For example, Matafwali and Mofu (2023) in Zambia found that indigenous games improved children's executive functions and motor planning, Riley et al. (2023) in Canada highlighted their role in fostering cultural identity and engagement, and Matsekoleng et al. (2024) reported improved classroom collaboration in South Africa. However, these studies rarely address the structured teaching of scientific concepts such as force, motion, or balance, especially in early childhood contexts. This makes the integration of traditional games into science learning both a novel and necessary area of investigation.

Based on a preliminary needs analysis conducted in three urban preschools in Bandarlampung, Indonesia, 72% of early childhood teachers reported limited instructional tools for introducing science concepts through movement. In contrast, 68% stated that traditional games were rarely integrated into formal learning despite their popularity during recess. Informal interviews also revealed that both teachers and parents perceived a disconnect between science instruction and children's hands-on experiences, particularly in understanding abstract concepts like force, motion, or environmental changes. To further substantiate this, a small survey with 15 preschool teachers and 20 parents revealed that 73% observed minimal incorporation of movement-based activities in science lessons, and 65% noted that learning remained dominated by worksheet-based or demonstration-only activities. These findings confirm that cognitive and motor stimulation in formal preschool education remains low, justifying the need for more integrated and engaging learning strategies.

Games are a fundamental mechanism in early childhood cognitive and motor development, facilitating creativity, problem-solving, and critical thinking (Biino et al., 2023; Ramesh, 2022). However, not all play experiences provide equal educational benefits. Strategic play, which involves decision-making, tactical reasoning, and coordination, has been shown to improve executive function and cognitive flexibility (Etokabeka, 2021; Gibb et al., 2021). Unlike passive or overly structured activities, Bentengan requires hands-on problem-solving, adaptive decision-making, and physical coordination (Iswinarti & Laily, 2024). This makes Bentengan a strong candidate for integrating movement-based learning with scientific inquiry. The interactive nature of the game aligns with constructivist theory, which posits that children construct knowledge through active experiences, and embodied cognition theory, which argues that bodily movement supports and shapes cognitive processes (Fugate et al., 2019; Light, 2021). Both frameworks justify why Bentengan is pedagogically suited to link abstract science concepts with lived physical experiences.

Motor development plays a crucial role in early childhood learning, as it directly influences neurological growth, spatial awareness, and executive function (Escolano-Pérez et al., 2021; Malambo et al., 2022; Shi & Feng, 2022). Research indicates that movement-based learning can foster higher cognitive engagement and enhance memory compared to sedentary instruction (Mavilidi et al., 2022; Wood, 2023). While structured sports and physical activity have been extensively studied, the educational role of traditional strategic games in preschool science learning has rarely been the primary focus (Yılmaz & Griffiths, 2023). Bentengan, which involves running, dodging, strategic thinking, and teamwork, presents a unique opportunity to investigate how movement-based learning fosters both cognitive and motor development in a preschool setting.

Early exposure to science learning in preschool education is crucial in shaping children's understanding of basic concepts such as force, motion, balance, and velocity (O'Connor et al., 2021; Ravanis, 2022; Siry et al., 2023). Research consistently shows that interactive, hands-on approaches significantly improve conceptual mastery in young children (Maričić et al., 2023). However, many preschool science lessons remain theoretical or rely on simple demonstrations, neglecting the potential of kinesthetic and play-based learning. Bentengan bridges this gap by providing physical activities that represent principles of force and motion, giving children concrete experiences to strengthen their conceptual understanding (Kersting et al., 2021; Macrine & Fugate, 2022).

Although the benefits of active learning and embodied cognition have been widely documented (Gordon & Ramani, 2021; Macrine & Fugate, 2021; McGowan et al., 2021; Jusslin et al., 2022), few studies have systematically examined traditional strategic games in Southeast Asian preschool contexts. This study addresses that gap by positioning Bentengan as an innovative and contextual learning model that integrates cultural heritage with contemporary educational practice. Its contribution lies in offering an integrative model that combines cognitive, motor, and social learning outcomes through culturally embedded practices, thereby expanding existing literature on embodied learning, science pedagogy, and culturally responsive education.

Therefore, this study investigates the effectiveness of Bentengan in improving preschool children's cognitive and motor skills through science learning. Specifically, it examines (1) the impact of Bentengan on conceptual understanding, gross motor skills, and fine motor skills, (2) how strategic play-based science learning affects collaboration, problem-solving, and engagement, and (3) how conceptual understanding and motor skill development interact to shape learning experiences. By addressing these questions, this research contributes both practically—by offering a culturally grounded, inclusive instructional model—and theoretically, by deepening our understanding of the interplay between embodied cognition, constructivism, and early science education.

## METHODS

This study employed a mixed-methods sequential explanatory design (Creswell & Creswell, 2023), integrating a quasi-experimental pretest–posttest control group design in the quantitative phase and a qualitative approach to provide explanatory depth. This design allowed for systematic hypothesis testing using numerical data while also capturing contextual insights into children's learning experiences (Rogers & Revesz, 2019).

The participants were 60 preschool children aged 4–6 years from several preschool education institutions in Bandar Lampung, Indonesia, selected through purposive sampling to ensure developmental comparability, with both boys and girls represented (51.6% male, 48.4% female). Inclusion criteria required regular school attendance and parental consent, while children with diagnosed developmental delays or sensory impairments were excluded. The children were randomly assigned to an experimental group (n = 30), which experienced Bentengan-based science learning, and a control group (n = 30), which received conventional teacher-centered learning, characterized by lectures, simple demonstrations, and worksheet-based activities without integration of play or physical movement.

The intervention was structured around the principles of scaffolded instruction (Faber et al., 2024). Teachers introduced the Bentengan game through storytelling and live demonstrations, followed by small-group practice of movements such as running, tagging, and dodging. Complexity and rules were gradually increased, ensuring accessibility while encouraging strategic collaboration and adaptive reasoning. Table 1 presents an overview of the intervention procedures.

**Table 1.** Intervention Procedures

| Phase | Description |
|---|---|
| Pre-Intervention (Week 1) | Pretest of cognitive and motor skills. The experimental group was introduced to Bentengan through stories, demonstrations, and guided practice. The control group received lecture- and worksheet-based science lessons. |
| Intervention (Week 2 to 5) | The experimental group engaged in Bentengan-based science sessions linking movement to concepts (force, motion, balance, environment). The control group followed conventional lessons with minimal physical involvement. |
| Post-Intervention (Week 6) | Posttest conducted for both groups. Observations, interviews, and sociometric mapping documented children's engagement, collaboration, and problem-solving. |

Three primary instruments were used: (1) Science Concept Recognition Test (SCRT) to assess conceptual understanding of force, motion, balance, and environmental interactions; (2) Gross Motor Function Measure (GMFM-88) to evaluate agility, balance, and directional changes; and (3) Movement Assessment Battery for Children (MABC-2) to assess fine motor coordination and bilateral control. Complementary data were collected through structured interviews, teacher/parent questionnaires, and sociometric mapping of peer collaboration. Details of validity, reliability, and extended instrument specifications are provided in the Appendix (Tables A1 and A2).

Quantitative data were analyzed using Two-Way ANOVA to examine main and interaction effects between instructional approach (Bentengan vs. conventional) and outcome variables (SCRT, GMFM-88, MABC-2), supported by effect size calculations (Cohen's d). Qualitative data were analyzed using thematic analysis following Clarke & Braun's (2017) framework, while sociometric network analysis was conducted using UCINET software (Shabankareh et al., 2024) to map peer collaboration patterns.

## RESULTS AND DISCUSSION

This study evaluated the effectiveness of the Bentengan game as an interactive, movement-based approach in early childhood science learning, specifically in improving cognitive development, motor skills, and social interactions. This study employed both quantitative and qualitative analyses to comprehensively assess learning outcomes. The experimental group that participated in Bentengan-based learning showed a significant increase in learning outcomes compared to the control group that received traditional learning. These findings reinforce the consensus that game-based learning can promote a deeper conceptual understanding and better motor development than passive instructional methods (Parker & Thomsen, 2019; Ebbeck et al., 2020; Jain, 2021). Previous research has demonstrated that integrating culturally relevant games into STEM learning environments can enhance student engagement, improve concept retention, and facilitate the daily application of scientific principles (Van Ingen et al., 2018; Johnson & Elliott, 2020; Li et al., 2021).

Assumption testing was performed prior to conducting parametric analysis to ensure the validity of the statistical tests. The Shapiro-Wilk test for normality ($p > 0.05$) and Levene's test for homogeneity of variance ($p > 0.05$) confirmed that the data met the assumptions required for Two-Way ANOVA. The results are presented in Table 2, which verifies that the data set is normally distributed and the variances are equal across groups.

**Table 2.** Test of Assumptions of Normality and Homogeneity of Variance

| Variable | Group | Shapiro-Wilk (p-value) | Normality Assumption | Levene's test (p-value) | Homogeneity Assumption |
|---|---|---|---|---|---|
| Science Concept Recognition Test (SCRT) | Experimental | 0.067 | Normal | 0.082 | Homogenous |
| | Control | 0.092 | Normal | 0.095 | Homogenous |
| Gross Motor Function Measure (GMFM-88) | Experimental | 0.071 | Normal | 0.078 | Homogenous |
| | Control | 0.084 | Normal | 0.081 | Homogenous |
| Movement Assessment Battery for Children (MABC-2) | Experimental | 0.089 | Normal | 0.076 | Homogenous |
| | Control | 0.071 | Normal | 0.080 | Homogenous |

Once these assumptions were met, the study evaluated the effectiveness of the intervention. Two-way ANOVA was conducted to test the main effects of instructional methods and their interaction effects on developmental outcomes. The results are summarized in Table 3.

**Table 3.** Two-Way ANOVA Results for Cognitive and Motor Development

| Source | df | Mean Square | F | Sig. (p-value) | Partial Eta Squared |
|---|---|---|---|---|---|
| Corrected Model | 9 | 1872.814 | 84.216 | < 0.001 | 0.945 |
| Group (Experimental vs. Control) | 1 | 5725.847 | 278.452 | < 0.001 | 0.928 |
| SCRT (Cognitive Development) | 1 | 481.357 | 23.014 | < 0.001 | 0.165 |
| GMFM-88 (Gross Motor Skills) | 1 | 624.121 | 29.215 | < 0.001 | 0.192 |
| MABC-2 (Fine Motor Coordination) | 1 | 361.842 | 17.342 | < 0.001 | 0.135 |
| Group × SCRT | 1 | 182.917 | 8.714 | 0.004 | 0.074 |

| Source | df | Mean Square | F | Sig. (p-value) | Partial Eta Squared |
|---|---|---|---|---|---|
| Group × GMFM-88 | 1 | 218.527 | 10.017 | 0.003 | 0.083 |
| Group × MABC-2 | 1 | 139.213 | 6.841 | 0.011 | 0.056 |
| SCRT × GMFM-88 | 1 | 157.628 | 7.862 | 0.008 | 0.067 |
| SCRT × MABC-2 | 1 | 144.831 | 7.215 | 0.010 | 0.062 |
| GMFM-88 × MABC-2 | 1 | 168.412 | 8.132 | 0.006 | 0.069 |
| SCRT × GMFM-88 × MABC-2 | 1 | 112.351 | 5.314 | 0.024 | 0.047 |

The results of the Two-Way ANOVA analysis in Table 3 show strong evidence that the Bentengan game-based intervention significantly improved the cognitive development and motor skills of preschool children. The main effect of group ($F = 278.452$, $p < 0.001$, $\eta^2 = 0.928$) showed that children in the experimental group experienced a significantly higher increase in understanding science concepts (SCRT), gross motor skills (GMFM-88), and fine motor coordination (MABC-2) compared to the control group. This effect can be observed directly in the field, where children in the experimental group actively interacted with their environment and demonstrated the ability to apply science concepts through play. This finding strongly supports the embodied cognition theory, which posits that sensorimotor engagement enhances cognitive processes and retention by establishing a direct connection between action and thought (Tsay et al., 2024). These findings are not only consistent with previous empirical studies but also demonstrate a clear embodiment of constructivist principles, where children actively build their own understanding through direct engagement with physical tasks. The strong improvement across SCRT, GMFM-88, and MABC-2 illustrates how embodied cognition, where knowledge is grounded in sensorimotor activity, supports children in transforming play experiences into conceptual learning. Previous research has also demonstrated that children learn more effectively when they can physically manipulate and experience scientific principles rather than passively receiving information (Kontra et al., 2015; Mayer et al., 2023). Thus, the findings in this study align with the broader understanding that early STEM education should incorporate hands-on, movement-based experiences to enhance concept retention.

The main effect of SCRT ($F = 23.014$, $p < 0.001$, $\eta^2 = 0.165$) indicated that children's understanding of basic science concepts significantly improved as a result of the intervention. Field observations revealed that children in the experimental group naturally explored the concepts of force and motion, for example, running faster when being chased, stopping suddenly, and pushing a friend forward, reflecting an intuitive understanding of Newtonian mechanics. A particularly telling moment of this understanding occurred when a child said, "If I push my friend on the grass, he does not move much, but on the basketball court, he slides!", which directly relates to the concepts of friction and surface resistance. These findings align with Stephenson et al. (2023), who emphasized that play-based environments allow children to test hypotheses and refine their understanding through direct experience. This outcome also embodies the constructivist view that knowledge is actively constructed when learners engage with actual contexts. The fact that children could articulate concepts such as friction without formal terminology reflects embodied cognition in action, where lived physical experiences serve as anchors for abstract reasoning.

In line with the Merdeka Curriculum, which encourages active learning and inquiry-based strategies such as Discovery Learning, the Bentengan-based intervention was designed to move beyond traditional lecturing. The learning process followed the discovery cycle, beginning with observation during play, followed by exploration of phenomena, formulating explanations through teacher-guided reflection, and reinforcing concepts via structured discussion. For example, after a Bentengan session, children were prompted to explain why their movements changed on different surfaces or how pushing with varying force affected motion. These moments of guided inquiry ensured that the learning experience was consistent with constructivist principles and the Discovery Learning model, where children construct meaning from physical experiences.

In contrast, the control group received science learning through teacher-centered lectures and worksheet-based tasks, which, although common in many preschools, lacked physical exploration and collaborative discussion. This passive approach resulted in limited conceptual internalization, as observed in their inability to articulate the influence of surface texture on motion. Fiorella (2023) and Mikolaj (2019) similarly noted that verbal explanations alone are often insufficient for young learners to form durable scientific understanding. Thus, while the control group primarily relied on auditory and visual channels for concept acquisition, the experimental group benefited from multisensory, embodied learning.

These findings underscore the need to design early childhood science experiences that align with national curricular reforms, which emphasize student autonomy, contextual relevance, and active engagement. The fort-based learning using Bentengan did not simply replace lectures with play but strategically embedded scientific inquiry within culturally relevant physical activity. This model exemplifies how indigenous games can be harmonized with modern pedagogical frameworks to foster meaningful, deep learning in preschool education.

The main effect of GMFM-88 ($F = 29.215$, $p < 0.001$, $\eta^2 = 0.192$) highlighted a significant improvement in gross motor skills in the experimental group. Field observations showed that children gradually improved their running coordination, reaction speed, and spatial awareness during the intervention. Teachers noted that many children initially had difficulty maneuvering around obstacles, but by the end of the program, they were able to control acceleration, deceleration, and balance when running on uneven surfaces. This finding aligns with previous studies that suggest early childhood movement experiences contribute to the development of neuromuscular control, proprioception, and postural stability (Silva-Moya et al., 2022). The role of the outdoor environment in shaping children's motor skills and environmental awareness is also reflected in this study, as children ran on grass fields, slippery surfaces after rain, and paved play areas while adjusting their movements. One child said, "Running after it rains is harder because my shoes get slippery!" This indicates direct engagement with environmental science concepts, such as friction and the effects of water on surfaces. Similar findings have been reported in studies of nature-based learning, where interactions with natural materials help children hone their movement efficiency and develop environmental literacy (Fang et al., 2023; El-Aasar et al., 2024). From the perspective of embodied cognition, these gross motor improvements are not separate from learning but integral to it; movement serves as a medium through which children explore cause-and-effect relations. Constructivism explains this progression as a process of iterative adaptation, where children refine their understanding of force and balance as they physically navigate diverse terrains.

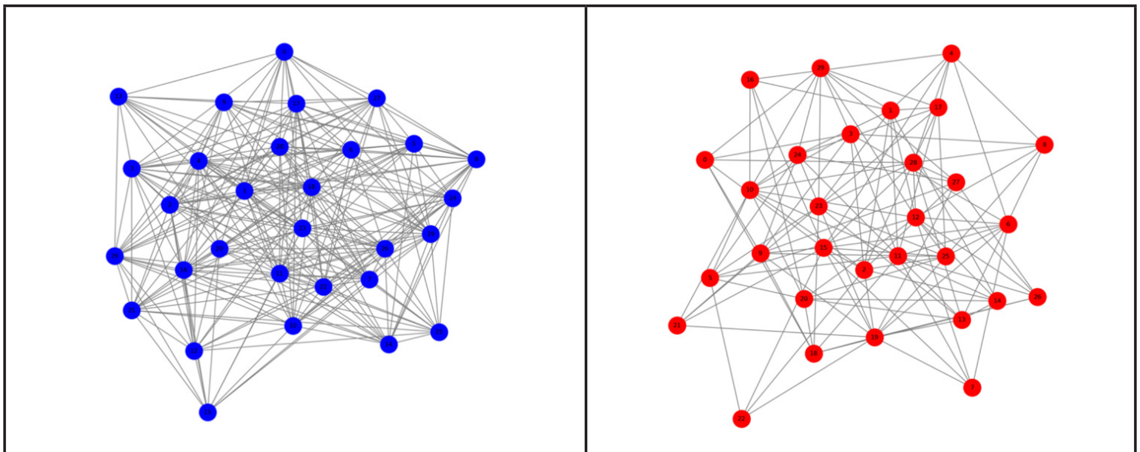
The significant effect of MABC-2 ($F = 17.342$, $p < 0.001$, $\eta^2 = 0.135$) indicates that the intervention also improved fine motor coordination, especially in tasks requiring precision, reaction time, and object manipulation. In the play-integrated environmental science activities, children were asked to pick up leaves, twigs, and other small objects from the ground while maintaining balance, which strengthened hand-eye coordination and dexterity. One key moment occurred when children were asked to compare dry and wet leaves, with one child commenting, "The wet leaf is heavier, and it sticks to my hand!" This reflected their early engagement with chemical concepts such as absorption, weight, and differences in texture in organic materials. These findings align with research indicating that hands-on, manipulative activities enhance preschool children's ability to recognize and categorize materials based on their properties (Byrne et al., 2023). A control group that did not engage in these activities showed lower improvements in fine motor coordination, as they were not required to handle objects in a dynamic, interactive context. The role of fine motor involvement in cognitive learning has also been widely discussed in the literature, emphasizing that manipulation of real objects from an early age can strengthen sensory integration and conceptual understanding (Chandler et al., 2021; Shi & Feng, 2022). The observed gains in fine motor coordination further illustrate embodied cognition, where manipulating physical objects deepens conceptual understanding by linking sensory inputs to abstract categories. Within a constructivist frame, children actively reorganize their knowledge structures when new tactile experiences, such as contrasting textures of leaves, challenge prior assumptions, thereby fostering conceptual growth.

The most striking finding was a three-way interaction effect (SCRT × GMFM-88 × MABC-2: $F = 5.314$, $p = 0.024$, $\eta^2 = 0.047$), highlighting the complex interrelationships between cognitive, gross motor, and fine motor skills in early childhood science learning. This interaction was particularly evident in environmental science exploration activities, where children directly interacted with living things, soil textures, and other natural elements through games. In one session, as children ran across a grassy field and observed insects and plants, one child enthusiastically commented, "I see little ants running! They got faster when I lifted the rock!" This comment reflected an understanding of animal behavior and environmental adaptation. Another child also commented, "The ground is wet here, so it is easier to make footprints!" This indicates an understanding of the differences in soil composition due to varying moisture levels. This observation aligns with research indicating that direct interaction with the natural environment can foster scientific curiosity and ecological literacy from an early age, as well as reinforce the importance of place-based and inquiry-based STEM education in preschool education (García-González & Schenetti, 2022; Bjerknes et al., 2024).

This three-way interaction illustrates the essence of embodied cognition, where physical movement (gross motor), object manipulation (fine motor), and conceptual reasoning (cognitive) converge to shape holistic learning. Rather than treating motor and cognitive development as parallel but separate, the findings show that the body becomes the medium through which children construct scientific understanding. Constructivism further explains this integration as a process of active meaning-making; children do not passively absorb knowledge, but rather reorganize their cognitive schemas through repeated, multisensory interactions with the environment. In Bentengan, every run, dodge, or tactile exploration of leaves and soil becomes both a physical act and a cognitive scaffold, helping children internalize abstract principles such as force, friction, and adaptation.

Quantitative and qualitative evidence from this study confirms that movement-based learning not only improves cognitive and motor skills but also promotes deeper engagement with environmental science concepts. The experimental group showed higher curiosity, engagement, and problem-solving behaviors, especially when interacting with natural elements such as leaves, water, insects, and soil. This supports the argument that science learning should be multisensory, physically interactive, and immersive in the environment to optimize learning outcomes in early-age children (Cuturi et al., 2022; Aulina et al., 2024). Interestingly, these findings also suggest that science education should not separate physics, biology, and chemistry as distinct domains, but rather integrate them through active, hands-on experiences. By running, touching, observing, and manipulating fundamental elements in the environment, children build a connected understanding of forces, motion, environmental science, and the properties of materials—reaffirming that early childhood STEM education should be dynamic, experiential, and inquiry-oriented.

Sociometric network analysis visualizes peer interactions and social connectedness in both the experimental and control groups, revealing important differences in the collaborative structures that emerged during the intervention. The experimental group network (Figure 1a) appears denser and more interconnected, indicating strong peer collaboration and high social engagement. In contrast, the control group network (Figure 1b) is more fragmented, indicating weaker social interactions and limited opportunities for collaboration.



a. Sociometric Network - Experimental Group (n=30) | b. Sociometric Network - Control Group (n=30)

**Figure 1**. Sociometric Network Analysis using UCINET

The denser sociometric network in the experimental group is consistent with quantitative and qualitative findings, which support the argument that interactive, movement-based learning environments foster social connections and collaborative problem-solving skills (MacKnight, 2021; Sun et al., 2022). This finding is particularly significant in the context of early childhood education, where peer interactions play a crucial role in driving cognitive and social development (Johnstone et al., 2022).

The experimental group exhibited a highly connected social network, characterized by more frequent and meaningful peer interactions during the intervention. In Bentengan-based learning sessions, children actively communicated, strategized, and solved problems together, leading to stronger social bonds. This was reflected in children's statements such as:

"We have to take turns running, so that there is always someone ready next!" (Child)

"You cover me, I will take the other base!" (Child)

These statements indicate a collaborative mindset and role-sharing, proving that Bentengan-based learning naturally fosters teamwork skills. This finding aligns with research suggesting that structured play environments foster social relationships among children through shared goals and collective decision-making.

Teachers also noted a visible change in the social dynamics of the classroom, with previously passive and withdrawn preschool children becoming more confident and engaged in group activities. One teacher stated:

"Some of the children who were usually quiet and shy became more active because the game gave them clear roles and goals."

This suggests that the game provided an inclusive environment where all children felt comfortable interacting, supporting the social constructivist view that peer collaboration enhances learning outcomes (Qureshi et al., 2023).

In contrast, the sociometric network of the control group appeared less dense, with fewer social connections and more isolated nodes. This suggests that conventional teacher-led learning does not provide enough space for peer collaboration. Observations revealed that children in the control group engaged in minimal verbal interaction during learning and were more engaged in individual, worksheet-based tasks. This finding aligns with the quantitative results, which show that the control group exhibited significantly lower improvements in both cognitive and motor development (see Table 3).

Parents also noticed a lack of social engagement in the learning process. One parent said:

"He never talks about playing with his friends at school; he only talks about what the teacher says."

This statement highlights the passive nature of traditional learning methods, which often fail to foster the social motivation necessary for active learning. This finding aligns with studies that demonstrate the significant impact of interactive learning environments on social-emotional skills compared to teacher-centered approaches (Huang & Lajoie, 2023).

One important insight from this sociometric analysis is that children with stronger social connections also showed higher learning gains in science concepts. The peer interactions facilitated by Bentengan helped children articulate scientific principles, engage in hands-on experiments, and solidify understanding through collaborative dialogue. This aligns with research indicating that socially engaged students tend to perform better in STEM subjects, primarily due to increased engagement (Latifi et al., 2021).

For example, during the game, a group of children discussed the effects of force and motion while strategizing:

"If we all run fast together, we can get to the base before they can touch us!"

This statement demonstrates the real-time application of Newton's physics principles, which strengthens the embodied learning hypothesis. The collaborative learning aspect of the game enables children to actively test and refine their understanding of physics through social interaction, thereby further strengthening the findings of significant improvements in science concept recognition (SCRT) presented in Table 3.

This study demonstrates that integrating the traditional Bentengan game into early childhood science learning effectively enhances conceptual understanding, motor skills, and social collaboration. Unlike previous studies, this study reveals a reciprocal relationship between cognitive, motor, and social development in an interactive and engaging learning context. The use of quantitative analysis methods (Two-Way ANOVA), sociometric network analysis, and thematic qualitative analysis strengthens the findings that physical engagement in strategic play improves children's concept retention and social interaction. Furthermore, this study highlights the importance of integrating cultural and movement-based learning approaches into early childhood science curricula.

Conceptually, this study contributes to the development of embodied cognition studies in early childhood science education by adding empirical evidence on how sensorimotor experiences can strengthen scientific thinking processes. On the other hand, this study expands the realm of play-based learning by incorporating social analysis through a sociometric network approach, providing a new perspective on the dynamics of interaction in active learning contexts. These findings also provide practical contributions to the design of locally contextualized and culturally relevant curricula, while strengthening the theoretical foundation of movement-based learning as a multidimensional approach that supports cognitive, social, and motor development simultaneously.

However, this study is limited by its narrow geographic scope and has not examined the long-term retention of concepts. Therefore, further research is recommended to adopt a longitudinal design, explore more diverse educational contexts, consider game adaptations for children with special needs, and utilize motion tracking technology or artificial intelligence-based analysis to expand the understanding of the relationship between physical activity and cognitive development in early childhood.

## CONCLUSION

This study confirms that the traditional game Bentengan can serve as a contextual model for early childhood science learning, effectively integrating cognitive, motor, and social-emotional development. Empirical evidence suggests that embodied interaction during play enhances preschoolers' conceptual understanding of force, motion, balance, and environmental phenomena, while also strengthening their gross and fine motor coordination. Theoretically, these findings contribute to embodied cognition studies by demonstrating how sensorimotor engagement functions as a foundation for abstract scientific reasoning in STEM domains. Practically, the integration of culturally grounded games provides a locally relevant and engaging alternative to conventional instruction, positioning Bentengan as a sustainable approach for culture-based preschool learning that aligns with current curriculum reforms and the broader agenda of inclusive, active, and meaningful early science education.

## REFERENCES

Alotaibi, M. S. (2024). Game-based learning in early childhood education: A systematic review and meta-analysis. *Frontiers in Psychology*, *15*, 1307881.

Arbi, Z. E., Mnejja, K., Negra, Y., Albaret, J.-M., Rebai, H., & Sahli, S. (2025). Movement Assessment Battery for Children—second edition (MABC-2): Aspects of reliability for Tunisian children (age band 1). *Sport Sciences for Health*.

Aslan, S., Agrawal, A., Alyuz, N., Chierichetti, R., Durham, L. M., Manuvinakurike, R., Okur, E., Sahay, S., Sharma, S., Sherry, J., Raffa, G., & Nachman, L. (2022). Exploring Kid Space in the wild: A preliminary study of multimodal and immersive collaborative play-based learning experiences. *Educational Technology Research and Development*, *70*(1), 205–230.

Aulina, C. N., Masitoh, S., & Arianto, F. (2024). Whole Brain Teaching and Multisensory Environments on Cognitive Science Development: Moderated by Children's Learning Preferences. *IJORER: International Journal of Recent Educational Research*, *5*(4), 963–977.

Ayaz-Alkaya, S., & Akca, A. (2025). The Impact of Traditional Children's Games on Internet Use, Social Skills, and Stress Level: A Cross-Sectional Design. *Journal of Transcultural Nursing*, *36*(1), 84–91.

Bazaz, S. B., Hasankala, Q. Y., Shojaee, A. A., & Unesi, Z. (2018). The effects of traditional games on preschool children's social development and emotional intelligence: A two-group, pretest-posttest, randomized, controlled trial. *Modern Care Journal*, *15*(1), 1–5.

Bianconi, A., Fiore, M., Zauli, E., Acuti Martellucci, C., Rosso, A., Dallolio, L., Flacco, M. E., & Manzoli, L. (2024). How strong is the evidence supporting the WHO guidelines on physical activity, sedentary behaviour and sleep in early childhood? *European Journal of Clinical Investigation*, *54*(12), e14294.

Biino, V., Tinagli, V., Borioni, F., & Pesce, C. (2023). Cognitively enriched physical activity may foster motor competence and executive function as early as preschool age: A pilot trial. *Physical Education and Sport Pedagogy*, *28*(4), 425–443.

Bjerknes, A.-L., Wilhelmsen, T., & Foyn-Bruun, E. (2024). A Systematic Review of Curiosity and Wonder in Natural Science and Early Childhood Education Research. *Journal of Research in Childhood Education*, *38*(1), 50–65.

Byrne, E. M., Jensen, H., Thomsen, B. S., & Ramchandani, P. G. (2023). Educational interventions involving physical manipulatives for improving children's learning and development: A scoping review. *Review of Education*, *11*(2), e3400.

Carolan, B. V. (2013). *Social network analysis and education: Theory, methods & applications*. Sage Publications.

Chandler, M. C., Gerde, H. K., Bowles, R. P., McRoy, K. Z., Pontifex, M. B., & Bingham, G. E. (2021). Self-regulation moderates the relationship between fine motor skills and writing in early childhood. *Early Childhood Research Quarterly*, *57*, 239–250.

Clarke, V., & Braun, V. (2017). Thematic analysis. *The Journal of Positive Psychology*, *12*(3), 297–298.

Creswell, J. W., & Creswell, J. D. (2023). *Research design: Qualitative, quantitative, and mixed methods approaches* (Sixth Edition). Sage publications.

Cuturi, L. F., Cappagli, G., Yiannoutsou, N., Price, S., & Gori, M. (2022). Informing the design of a multisensory learning environment for elementary mathematics learning. *Journal on Multimodal User Interfaces*, *16*(2), 155–171.

Devi, A. (2022). Understanding play participants' perspectives in play-based learning: A cultural-historical analysis in a home context. *Pedagogies: An International Journal*, *17*(2), 139–161.

Ebbeck, M., Yim, H. Y. B., & Lee, L. W. M. (2020). Play-based learning. In *Teaching Early Years* (pp. 185–200). Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9781003117704-14/play-based-learning-marjory-ebbeck-hoi-yin-bonnie-yim-lai-wan-maria-lee

El-Aasar, M., Shafik, Z., & Abou-Bakr, D. (2024). Outdoor learning environment as a teaching tool for integrating education for sustainable development in kindergarten, Egypt. *Ain Shams Engineering Journal*, *15*(4), 102629.

Escolano-Pérez, E., Sánchez-López, C. R., & Herrero-Nivela, M. L. (2021). Early environmental and biological influences on preschool motor skills: Implications for early childhood care and education. *Frontiers in Psychology*, *12*, 725832.

Etokabeka, E. M. de C. (2021). *The role of structured play in facilitating preschool learners' executive functions* [PhD Thesis, University of Pretoria]. https://repository.up.ac.za/handle/2263/83749

Faber, T. J. E., Dankbaar, M. E. W., Van Den Broek, W. W., Bruinink, L. J., Hogeveen, M., & Van Merriënboer, J. J. G. (2024). Effects of adaptive scaffolding on performance, cognitive load and engagement in game-based learning: A randomized controlled trial. *BMC Medical Education*, *24*(1), 943.

Fang, W.-T., Hassan, A., & LePage, B. A. (2023). Environmental Literacy. In W.-T. Fang, A. Hassan, & B. A. LePage, *The Living Environmental Education* (pp. 93–126). Springer Nature Singapore.

Fiorella, L. (2023). Making Sense of Generative Learning. *Educational Psychology Review*, *35*(2), 50.

Fleer, M., & Quiñones, G. (2013). An Assessment Perezhivanie: Building an Assessment Pedagogy for, with and of Early Childhood Science Learning. In D. Corrigan, R. Gunstone, & A. Jones (Eds.), *Valuing Assessment in Science Education: Pedagogy, Curriculum, Policy* (pp. 231–247). Springer Netherlands.

Fugate, J. M. B., Macrine, S. L., & Cipriano, C. (2019). The role of embodied cognition for transforming learning. *International Journal of School & Educational Psychology*, *7*(4), 274–288.

García-González, E., & Schenetti, M. (2022). Education in nature and learning science in early childhood: A fertile and sustainable symbiosis. *Journal of Outdoor and Environmental Education*, *25*(3), 363–377.

Gibb, R., Coelho, L., Van Rootselaar, N. A., Halliwell, C., MacKinnon, M., Plomp, I., & Gonzalez, C. L. (2021). Promoting executive function skills in preschoolers using a play-based program. *Frontiers in Psychology*, *12*, 720225.

Gordon, R., & Ramani, G. B. (2021). Integrating embodied cognition and information processing: A combined model of the role of gesture in children's mathematical environments. *Frontiers in Psychology*, *12*, 650286.

Greenfield, D. B. (2015). Assessment in Early Childhood Science Education. In K. Cabe Trundle & M. Saçkes (Eds.), *Research in Early Childhood Science Education* (pp. 353–380). Springer Netherlands.

Harvey, A. R. (2017). The gross motor function measure (GMFM). *Journal of Physiotherapy*, *63*(3), 187.

Huang, X., & Lajoie, S. P. (2023). Social emotional interaction in collaborative learning: Why it matters and how can we measure it? *Social Sciences & Humanities Open*, *7*(1), 100447.

Huber, S. E., Kiili, K., Nebel, S., Ryan, R. M., Sailer, M., & Ninaus, M. (2024). Leveraging the Potential of Large Language Models in Education Through Playful and Game-Based Learning. *Educational Psychology Review*, *36*(1), 25.

Iswinarti, I., & Laily, W. N. (2024). Increasing Moral Emotions Through Traditional Games of Gobak sodor and Bentengan Using the Experiential Learning Method. *Indigenous: Jurnal Ilmiah Psikologi*, *9*(1), 54–68.

Jain, P. S. (2021). *The potentiality of play: The shifting design language of play-based learning* [PhD Thesis]. https://napier-repository.worktribe.com/output/2799235

Johnson, A., & Elliott, S. (2020). Culturally Relevant Pedagogy: A Model To Guide Cultural Transformation in STEM Departments. *Journal of Microbiology & Biology Education*, *21*(1), 05.

Johnstone, A., Martin, A., Cordovil, R., Fjørtoft, I., Iivonen, S., Jidovtseff, B., Lopes, F., Reilly, J. J., Thomson, H., & Wells, V. (2022). Nature-based early childhood education and children's social, emotional and cognitive development: A mixed-methods systematic review. *International Journal of Environmental Research and Public Health*, *19*(10), 5967.

Jusslin, S., Korpinen, K., Lilja, N., Martin, R., Lehtinen-Schnabel, J., & Anttila, E. (2022). Embodied learning and teaching approaches in language education: A mixed studies review. *Educational*

*Research Review*, *37*, 100480.

Kersting, M., Haglund, J., & Steier, R. (2021). A Growing Body of Knowledge: On Four Different Senses of Embodiment in Science Education. *Science & Education*, *30*(5), 1183–1210.

Kontra, C., Lyons, D. J., Fischer, S. M., & Beilock, S. L. (2015). Physical Experience Enhances Science Learning. *Psychological Science*, *26*(6), 737–749.

Latifi, S., Noroozi, O., & Talaee, E. (2021). Peer feedback or peer feedforward? Enhancing students' argumentative peer learning processes and outcomes. *British Journal of Educational Technology*, *52*(2), 768–784.

Li, H., Forbes, A., & Yang, W. (2021). Developing Culturally and Developmentally Appropriate Early STEM Learning Experiences. *Early Education and Development*, *32*(1), 1–6.

Light, R. L. (2021). The body and learning through game sense. In *Game Sense for Teaching and Coaching* (pp. 35–44). Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9781003131557-6/body-learning-game-sense-richard-light

Lovakov, A., & Agadullina, E. R. (2021). Empirically derived guidelines for effect size interpretation in social psychology. *European Journal of Social Psychology*, *51*(3), 485–504.

MacKnight, C. B. (2021). Supporting critical thinking in interactive learning environments. In *The web in higher education* (pp. 17–32). CRC Press. https://www.taylorfrancis.com/chapters/edit/10.1201/9781003063803-2/supporting-critical-thinking-interactive-learning-environments-carol-macknight

Macrine, S. L., & Fugate, J. M. (2021). Translating embodied cognition for embodied learning in the classroom. *Frontiers in Education*, *6*, 712626.

Macrine, S. L., & Fugate, J. M. (2022). *Movement matters: How embodied cognition informs teaching and learning*. MIT Press. https://books.google.com/books?hl=id&lr=&id=YCM5EAAAQBAJ&oi=fnd&pg=PR11&dq=studies+on+embodied+cognition+in+science+education&ots=v_fMu-4N0h&sig=wdcU7_6Ey4GQvppkAAo3lgF5kOw

Malambo, C., Nová, A., Clark, C., & Musálek, M. (2022). Associations between fundamental movement skills, physical fitness, motor competency, physical activity, and executive functions in preschool age children: A systematic review. *Children*, *9*(7), 1059.

Maričić, M., Cvjetićanin, S., Adamov, J., Ninkovi□, S. O., & Anđić, B. (2023). How Do Direct and Indirect Hands-on Instructions Strengthened by the Self-Explanation Effect Promote Learning? Evidence from Motion Content. *Research in Science Education*, *53*(2), 231–251.

Matafwali, B., & Mofu, M. (2023). Exploring the feasibility of outdoor indigenous games and songs to enhance play-based pedagogy in early childhood education. *Journal of Childhood, Education & Society*, *4*(3).

Matsekoleng, T. K., Mapotse, T. A., & Gumbo, M. T. (2024). The role of indigenous games in education: A technology and environmental education perspective. *Diaspora, Indigenous, and Minority Education*, *18*(1), 68–82.

Mavilidi, M. F., Pesce, C., Benzing, V., Schmidt, M., Paas, F., Okely, A. D., & Vazou, S. (2022). Meta-analysis of movement-based interventions to aid academic and behavioral outcomes: A taxonomy of relevance and integration. *Educational Research Review*, *37*, 100478.

Mayer, R. E., Makransky, G., & Parong, J. (2023). The Promise and Pitfalls of Learning in Immersive Virtual Reality. *International Journal of Human–Computer Interaction*, *39*(11), 2229–2238.

McGowan, A. L., Gerde, H. K., Pfeiffer, K. A., & Pontifex, M. B. (2021). Physically active learning in preschoolers: Improved self-regulation, comparable quantity estimation. *Trends in Neuroscience and Education*, *22*, 100150.

Mikolaj, C. (2019). *Effective Instructional Strategies in Sixth Grade Inclusion Mathematics Classrooms: The Effect of Active and Passive Engagement on Concept Learning and Opportunity to Learn*. Duquesne University. https://search.proquest.com/openview/2b991bfbacdf596403420c895c5dd732/1?pq-origsite=gscholar&cbl=18750&diss=y

O'connor, G., Fragkiadaki, G., Fleer, M., & Rai, P. (2021). Early childhood science education from 0 to 6: A literature review. *Education Sciences*, *11*(4), 178.

Parker, R., & Thomsen, B. S. (2019). *Learning through play at school: A study of playful integrated pedagogies that foster children's holistic skills development in the primary school classroom*. https://research.acer.edu.au/learning_processes/22/

Qureshi, M. A., Khaskheli, A., Qureshi, J. A., Raza, S. A., & Yousufi, S. Q. (2023). Factors affecting students' learning performance through collaborative learning and engagement. *Interactive Learning Environments*, *31*(4), 2371–2391.

Ramesh, S. (2022). The Theories of Cognitive Development. In S. Ramesh, *The Political Economy of Human Behaviour and Economic Development* (pp. 143–180). Springer International Publishing.

Ravanis, K. (2022). Research trends and development perspectives in Early Childhood Science Education: An overview. In *Education Sciences* (Vol. 12, Issue 7, p. 456). MDPI.

Reimers, F. M. (2024). The sustainable development goals and education, achievements and opportunities. *International Journal of Educational Development*, *104*, 102965.

Riley, K., Froehlich Chow, A., Wahpepah, K., Humbert, M. L., Brussoni, M., Houser, N., & Erlandson, M. C. (2023). Etuaptmumk (Two-Eyed Seeing) in *Nature's Way-Our Way*: Braiding physical literacy and risky play through Indigenous games, activities, cultural connections, and traditional teachings. *AlterNative: An International Journal of Indigenous Peoples*, *19*(2), 426–436.

Rogers, J., & Revesz, A. (2019). Experimental and quasi-experimental designs. In *The Routledge handbook of research methods in applied linguistics* (pp. 133–143). Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9780367824471-12/experimental-quasi-experimental-designs-john-rogers-andrea-r%C3%A9v%C3%A9sz

Shabankareh, K., Hamidi, A., Soleymani, M. R., Sajadi, H. S., & Alavi, M. (2024). Faculty members as academic knowledge brokers in Iran's health sector: A social network analysis study. *Health Research Policy and Systems*, *22*(1), 53.

Shi, P., & Feng, X. (2022). Motor skills and cognitive benefits in children and adolescents: Relationship, mechanism and perspectives. *Frontiers in Psychology*, *13*, 1017825.

Silva-Moya, G., Méndez-Rebolledo, G., Valdes-Badilla, P., Gómez-Álvarez, N., & Guzmán-Muñoz, E. (2022). Effects of neuromuscular training on psychomotor development and active joint position sense in school children. *Journal of Motor Behavior*, *54*(1), 57–66.

Siry, C., Trundle, K. C., & Saçkes, M. (2023). Science education during the early childhood years: Research themes and future directions. In *Handbook of research on science education* (pp. 499–527). Routledge. https://api.taylorfrancis.com/content/chapters/edit/download?identifierName=doi&identifierValue=10.4324/9780367855758-20&type=chapterpdf

Stephenson, T., Fleer, M., Fragkiadaki, G., & Rai, P. (2023). Teaching STEM through play: Conditions created by the conceptual PlayWorld model for early childhood teachers. *Early Years*, *43*(4–5), 811–827.

Sun, C., Shute, V. J., Stewart, A. E., Beck-White, Q., Reinhardt, C. R., Zhou, G., Duran, N., & D'Mello, S. K. (2022). The relationship between collaborative problem solving behaviors and solution outcomes in a game-based learning environment. *Computers in Human Behavior*, *128*, 107120.

Sutapa, P., Pratama, K. W., Rosly, M. M., Ali, S. K. S., & Karakauki, M. (2021). Improving motor skills in early childhood through goal-oriented play activity. *Children*, *8*(11), 994.

Tsay, J. S., Kim, H. E., McDougle, S. D., Taylor, J. A., Haith, A., Avraham, G., Krakauer, J. W., Collins, A. G., & Ivry, R. B. (2024). Fundamental processes in sensorimotor learning: Reasoning, refinement, and retrieval. *Elife*, *13*, e91839.

Van Ingen, S., Davis, J., & Arndt, K. (2018). The synergy between integrated STEM lessons and culturally responsive teaching in elementary classrooms. *Research in the Schools*, *25*(1). https://eric.ed.gov/?id=EJ1246955

Vidal Carulla, C., Christodoulakis, N., & Adbo, K. (2021). Development of preschool children's executive functions throughout a play-based learning approach that embeds science concepts. *International Journal of Environmental Research and Public Health*, *18*(2), 588.

Wood, A. (2023). *Effects of a Movement-based Curriculum on the Motor and Cognitive Development of Preschool-aged Children*. https://trace.tennessee.edu/utk_graddiss/8159/

Yılmaz, E., & Griffiths, M. D. (2023). Children's social problem-solving skills in playing videogames and traditional games: A systematic review. *Education and Information Technologies*, *28*(9), 11679–11712.

## APPENDIX A – RESEARCH INSTRUMENTS AND SPECIFICATIONS

**Table A1.** Detailed Description of Research Instruments

| Instrument | Measurement Focus | Description | Example Item / Task | Source / Adaptation |
|---|---|---|---|---|
| Science Concept Recognition Test (SCRT) | Cognitive Understanding | Visual-based assessment of concepts: force, motion, balance, environment. Items presented in picture-based scenarios. | "Why can you run faster on a smooth floor than on grass?" | Fleer & Quiñones (2013); Greenfield (2015) |
| Gross Motor Function Measure (GMFM-88) | Gross Motor Skills | Measures agility, balance, and direction changes during running and stopping. | Children asked to run, stop abruptly, and maintain balance. | Harvey (2017) |
| Movement Assessment Battery for Children (MABC-2) | Coordination & Fine Motor Skills | Evaluates bilateral coordination, reaction speed, and small-object handling during dynamic play. | Picking up blocks/ objects while maintaining balance. | Arbi et al. (2025) |
| Collaborative Games Observation Rubric | Teamwork & Strategic Play | Teacher-rated rubric on children's task-sharing, adaptability, and peer communication. | Rating child's ability to rotate roles in a game scenario. | Researcher-developed |
| Sociometric Mapping | Social Interaction | Teacher-assisted mapping of peer choice, collaboration frequency, and group integration. | "Who do you like to play with most?" | Carolan (2013) |
| Teacher & Parent Questionnaire | Engagement & Perceived Learning | Likert-scale + open-ended items on child's engagement, curiosity, motor activity, and social behavior. | "My child talks about science concepts after playing Bentengan." | Researcher-developed |

## APPENDIX B – VALIDITY AND RELIABILITY RESULTS

**Table A2**. Reliability and Validity of Instruments

| Instrument | Reliability (Cronbach's Alpha) | Validity Approach | Notes |
|---|---|---|---|
| SCRT | 0.85 | Item difficulty analysis, expert panel validation | Items adjusted for age-appropriateness |
| GMFM-88 | 0.91 | Inter-rater reliability (≥85% expert agreement) | Standardized scoring maintained |
| MABC-2 | 0.89 | Correlation with standardized motor assessments | Adapted tasks to preschool play context |
| Observation Rubric | 0.83 | Inter-observer agreement, triangulation | Observed by two trained raters |
| Sociometric Mapping | – | Longitudinal consistency in peer choices | Used UCINET for network density validation |
| Teacher & Parent Questionnaire | 0.87 | Content validity through expert review | Cross-checked with classroom observations |