Effectiveness of play-based learning in enhancement of mathematical skills in children with down syndrome: a qualitative approach

Haina Liu

Chengdu Foreign Languages School, Pidu District, Chengdu City, Sichuan Province, China

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Abstract: This study investigates the effectiveness of Play-Based Learning (PBL) in garnering improvement in mathematical skills and proficiency among children with Down Syndrome (DS). This study is embedded within Parten's stages of play and developmental interaction approach and critically focuses on evaluating how PBL is effective in improving motor, cognitive and problem-solving skills. The study makes use of qualitative analysis using semi-structured interviews with five teachers whose responses reflect that collaborative and interactive play activities such as narration games or building blocks help in improving mathematical understanding and elevating critical thinking in children with DS. However, challenges concerning resource limitation, stakeholder resistance and inconsistent implementation pinpoint the need to implement standardized frameworks and increased support for achieving improved learning outcomes for DS children.

1. Background

Children with intellectual disabilities particularly suffer from impairments in cognition and socioemotional development. Play-based learning in recent times has emerged as a revolutionary pedagogical tool that helps children with Down Syndrome (DS) overcome intellectual challenges by fostering an interactive and engaging environment while learning. According to Kokol et al. (2020)[1], a serious game can be effective in distracting children with Down Syndrome from pain and simultaneously help in the development of motor and cognitive skills that make them excel in academics. This proves that the method includes both structured and non-structured activities with meaningful learning experiences which intrigue children and generate curiosity and intrinsic motivation to acquire newfound skills. Mathematical proficiency appears as a crucial learning skill that becomes elementary for improved academic performance and daily life expertise. However, the cognitive profiles of children suffering from DS reveal typical struggle with abstract reasoning due to lack of episodic memory, verbal reasoning and impairments in expressive language (Antonarakis et al., 2020)[2]. This implies that their competence in mastering mathematical concepts is also inherently weak owing to difficulties in reasoning. Thus, play-based learning can serve as a hands-on interactive activity for problem-solving, that stimulates both self-confidence and cognitive development, given the fact that children with DS are good at visual perceptions. Overall, play-based learning enriches the learning experience for DS students with memory deficits, giving them cues on how to enhance communication and collaboration with peer groups to receive help.

There are a plethora of studies focusing on the effectiveness of PBL on the cognitive development of children in general. However, fewer studies have been identified that focus on how mathematical skills are enhanced in children suffering from DS due to the integration of PBL in education plans. The study is anchored in discovering Parten's stages of play and the Developmental Interaction Approach to explore how cognitive and motor skill development is related to PBL in Down children, which ultimately improves their mathematical proficiency and critical problem solving, not without some challenges faced in this process. These key findings can be used to develop recommendations for empowering learning and social skills development in children with Down syndrome, to help them manifest optimum learning outcomes.

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1.1 Research Objectives

To investigate the effectiveness of play-based learning in improving mathematical proficiency due to enhanced cognitive and problem-solving abilities in children with DS.

1.2 Research Questions

What are the implications of play-based learning on the mathematical proficiency of children suffering from DS?

1.3 Theoretical Framework

This research is based on Parten's stages of play and the Developmental Interaction Approach to provide a comprehensive framework for investigating the role of play-based learning in the improvisation of mathematical proficiency skills in children with DS. According to Garwood (1982) solitary[3], unoccupied, onlooker, parallel, associative and cooperative are the Parten's stages of play. The progression of play behaviours in children ranges from solitary play to cooperative play, as proposed by Parten's stages of play. Each of the stages offers nuanced insights into the interplay of environmental engagement and peer skills within children at various stages of development. Similar views have been reflected in the philosophy of progressive education, echoed by the Developmental Interaction Approach proposed by John Dewey and the Bank Street School of Education. Hereby the children get a chance to be active learners, experientially enriched and socially involved to enhance their probability of intellectual development. This proves that play opportunities provide scope for enhancement of cognitive and social abilities, especially in students challenged with intellectual disabilities as in DS.

2. Methodology

The role of play-based learning in children with DS was investigated using a qualitative research design. Qualitative data analysis is favourable for understanding the in-depth details of the interplay between psychological constructs (Creswell & Poth, 2018)[4]. This study adapted the qualitative methodology of conducting semi-structured interviews with 5 educators who have experience in the implementation of play-based learning to teach mathematics to children affected with Down Syndrome. The data was collected either during face-to-face interaction or an interview over video conference, where based on the availability of the participants, the preferred mode was finalized. Each of the interviews spanned between 15-20 minutes and included questionnaires designed for educators. This also allowed the researchers to have a flexible idea in analyzing narratives to probe further into emerging themes (Kallio et al., 2016)[5]. The interviews were recorded with participant consent and transformed into a transcribed verbatim to analyse themes out of the data from interviews. In this context, Braun and Clarke (2006) validated the process of thematic analysis to identify, analyse, and report commonness and patterns within the qualitative data of the obtained interviews. All the participants had been assigned participant codes to maintain privacy. Lastly, an audit trial was run to confirm the dependability and detect any lapse in decision-making and documentation.

Ethical Considerations. Ethical approval was confirmed by the institutional review board (approval no.) before collecting data because the research included human participants. Informed consent was received from all the educators and their right to anonymity was assured against their voluntary participation. Any disclaimer for discussion of sensitive topics was duly acknowledged while maintaining privacy and confidentiality to eliminate the risk of potential stress.

3. Results

The key findings from the semi-structured interview reveal three broad emergent themes, from shared patterns of commonness. The results have been tabulated showing participants, their corresponding dialogue from the questionnaire and the resultant emergent theme (Appendix 1). On analysis of the responses of the educators, cognitive engagement and motor skill development through

play, play-based learning and problem-solving ability, and challenges against the implementation of play-based learning are identified as the three main emergent themes.

3.1 Theme 1: Cognitive Engagement and Motor Skill Development Through Play

2 out of 5 participants agree that the administration of play-based learning among children with DS exercised a positive impact on cognitive engagement and motor skill development. In this context, E1 states that "Activities like building blocks and interactive games help them grasp basic mathematical concepts". This shows the dual beneficial role of play-based learning that compels the child to ignore the pain induced due to the disability and focus on engaging in design through interactive tools that are customised to enhance mathematical skills remotely. E2 echoes the same observation by quoting "Games like hopscotch with numbers allow them to learn while staying active". This implies emphasising the significance of kinaesthetic activities that interlink movement and coordination with learning. These play-based tools thus employ the physical engagement strategy to overcome mental challenges. In this way, abstract concepts can be effectively simplified to the DS children, by utilisation of tangible learning experiences. Therefore, both motor coordination and comprehension of basic concepts in mathematics can be improvised by introducing tangible learning experiences and tactile manipulatives.

3.2 Theme 2: Play-Based Learning and Problem-Solving Ability

3 out of 5 educators emphasised on enhancement of problem-solving ability in children with DS due to play-based learning. Educator 3 stated, "Story-based activities with mathematical problems embedded in them are particularly useful". This underscores the importance of narrative-based play in the exemplification of critical thinking. In a similar context, Educator 5 pointed out that "Collaborative activities like building models with shapes encourage teamwork and critical thinking,". This statement proves that rather than engaging a child in solitary play, problem-solving ability can be enhanced by following a collaborative framework and team game models. Likewise, Educator 4 quotes, "Using real-life scenarios like shopping games to teach counting and basic arithmetic has been effective,". This suggests that the application of real-world examples in practical scenarios by integration of play can show sustained problem-solving skills in both individual and group activity formats, rather than directly exposing children with DS to mathematical challenges that might otherwise feel tough.

3.3 Challenges Against Implementation of Play-Based Learning

4 out of 5 participants confirm the challenges against the implementation of play-based learning in enhancing the mathematical proficiency of children with DS. Although play-based learning exhibits significant improvement in cognitive development, motor skills, and problem-solving ability, certain barriers hinder the adoption of the same within children with DS. This theme reflects on how the effectiveness of this intervention can be limited, and how its impact gets modulated in acquiring mathematical proficiency skills. Educator 1 noted, "We need more support in terms of funding for materials and tools." While Educator 4 quotes "We need more support in terms of funding for materials and tools." It is clear from these responses that the design of play-based learning needs to be mindfully crafted and designed such that it is capable of executing substantial and relevant outcomes. This requires ample funding and resources for long-term maintenance and systemic changes. Moreover, an increased investment is desired on behalf of the institutional authorities to facilitate the professional development of educators. Hereby Educator 3 mentions, "Convincing some stakeholders about the value of play-based learning can be difficult," suggesting a lack of consensus among decision-makers. This has been validated by Educator 5 in identifying the absence of standardised play-based learning approaches for the development of consistent policies and legislation to implement the same. Finally, Educator 5 remarked, "There's a lack of consistency in how play-based learning is implemented across schools". This shows the need for advocacy campaigns to assess the overall efficiency of play-based strategies in children with intellectual disabilities such as DS.

4. Discussion

Cognitive development and motor skill development in children suffering from DS is a big challenge. The key findings suggest that interactive play-based activities such as numerical hopscotch, building blocks and serious games aid in better physical movement and coordination and foster better mathematical understanding in DS children. These findings are supported by the preschool teachers who state that game-based learning instils the concept of numerical in DS children, who otherwise fail to grasp these concepts easily (Pinder, 2021)[6]. In this context, the Developmental Interaction Approach validates this fact by highlighting the necessity of experiential learning for cognitive growth. This implies that educators willing to use structured play-based tools in classrooms can guide the developmental capacity of students with intellectual disabilities. The scaffolding facilitated by play-based learning allows a firm grip on basic mathematical concepts required such as addition, counting, identifying sequences etc. For example, The snake and ladder game has been proven effective in curing locomotor dysfunctions in DS, which not only strengthens core muscle strength but teaches counting in the process (Anugrah et al., 2024)[7]. This matches with the observation of E1 that building blocks or number tiles can be used in classrooms to help the DS children calculate better by relating to real-world examples, which is otherwise difficult to manifest. Meanwhile, Parten's stages of play align with the cooperative and associative play stages, in which peer groups get actively involved with DS children to yield better results for play-based tasks. In recent times, Herath et al. (2023) pointed out the fact that visualisation of mathematical concepts and tactile tools allow improved exhibition of mathematical proficiency skills[8]. This was echoed by those who stated that the sense of numbers and arithmetic skills in DS students are found to be stronger in those who have experienced the use of tangible tools in classrooms. This informs that motor skills are enhanced via play-based learning that promotes motor skills and alleviates cognitive delays in children who are faced with difficulties in movement and coordination.

Play-based learning is crucial for the enhancement of problem-solving skills in DS children. Development of decision-making and execution of critical thinking are integral aspects of mathematical proficiency. However cognitive delays and memory deficits lead to difficulties with planning, cognitive flexibility and working memory in DS children (Tungate & Conners, 2021)[9]. This can be enhanced by introducing collaborative and narrative-based play activities. For instance: Fostering games that allow mind-body balance and using simple everyday materials allows for better conductance of geometry classes in DS children (Gil Clemente & Cogolludo-Agustín, 2019)[10]. Similarly simple exercises can be clubbed with simple mathematical challenges such as calculating bills and prices of goods to improve mathematical problem-solving in DS learners. Therefore, the reduction of cognitive load results in accelerated problem-solving. In this context, Parten's play stages depict the importance of collaborative frameworks in reaching common objectives. Hereby children with disabilities can participate and can utilise guided participation in peer activities and be involved with intimate peers to solve critical mathematical problems. This social engagement has been validated by previous research, which states that children with intellectual disabilities can master mathematical reasoning by participating in group activities. Therefore, interactive and fun play-based learning can be used to solve complex scenarios related to mathematics in real life, so that difficult concepts become relatable and engaging for DS students.

Despite relevant benefits, the implementation of play-based learning in DS children. Mathematical proficiency in DS children is attributed to problems with abstract reasoning and attention span, which makes them unable to understand concepts related to algebra and fractions (Patkee et al., 2020)[11]. These challenges need to be addressed by resource-intensive interventions that can yield better outcomes for DS learners. However, play-based learning often requires resource allocation and funding that are inconsistent across schools. Therefore, it becomes difficult to implement play-based learning as an intervention against disabilities that hinder mathematical proficiency. Moreover, educators need to be professionally trained to meet the special requirements of DS learners in inclusive classrooms. This is supported by Tay et al. (2022) who point out that the unique pedagogical needs of students with intellectual disabilities require to be taught under professionals who have undergone training[12]. Additionally, inconsistent outcomes are related to the absence of standardised

frameworks. For example: resistance from stakeholders such as educators in the implementation of play-based learning in mainstream classrooms because of lack of resources and inadequate training. This consensus among decision-making authorities is required to scale play-based learning as an effective long-term pedagogical tool to enhance mathematical skills in DS learners.

5. Conclusion

This study aims to explore the potential of play-based learning in fostering mathematical proficiency among children with DS. Play-based learning helps in nurturing cognitive, motor and problem-solving abilities that help in better conceptual understanding of algebraic, geometric and basic numerical problems. Moreover, working in groups and collaborative tasks aid in enhanced guidance to ace mathematical problems. Play-based tools mimicking real-life situations facilitate relatability in critical analysis of mathematical challenges, that bridge the gap between abstract concepts and problem-solving. However, challenges such as unavailability of funding and resources, inadequate professional training and stakeholder resistance restrict the wholehearted adoption and implementation of play-based learning to overcome mathematical challenges in DS children. Address these issues in the future needs standardised play-based learning frameworks, policy reforms and collaborative learning models to foster mathematical proficiency among DS learners.

Limitations and Recommendations for Future Study:

This study is limited by a small sample size, which leads to generalisability issues due to the lesser number of participants. Secondly, there are chances of reported bias in the case of interviews. Moreover, the reality of these findings needs to be verified by a quantitative approach, to ensure that the qualitative results are validated. Thus, there is a need to conduct longitudinal studies with larger sample sizes, which can yield a complete assessment of short-term and long-term benefits of play-based learning, in both social and academic contexts.

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Appendix 1

Participant	Dialogue from Questionnaire	Emergent Themes
Educator 1	"Activities like building blocks and interactive games help them grasp basic mathematical concepts."	Cognitive engagement and motor skill development through play
Educator 2	"Games like hopscotch with numbers allow them to learn while staying active."	Cognitive engagement and motor skill development through play
Educator 5	"There's a lack of consistency in how play-based learning is implemented across schools."	Challenges against the implementation of play-based learning
Educator 3	"Story-based activities with mathematical problems embedded in them are particularly useful."	Play-based learning and problem-solving ability
Educator 4	"Using real-life scenarios like shopping games to teach counting and basic arithmetic has been effective."	Play-based learning and problem-solving ability
Educator 1	The primary challenge is the lack of resources and training. Not all educators are equipped with the skills to design effective play-based activities.	Challenges against the implementation of play-based learning
Educator 5	"Collaborative activities like building models with shapes encourage teamwork and critical thinking."	Play-based learning and problem-solving ability
Educator 4	"We need more support in terms of funding for materials and tools."	Challenges against the implementation of play-based learning
Educator 3	Convincing some stakeholders about the value of play-based learning can be difficult."	Challenges against the implementation of play-based learning