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Development of a Bocce-Based Problem-Based Learning Module for Gross Motor Skills and Social Interaction in Children with Down Syndrome

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Abstract

Children with Down syndrome often experience delays in gross motor skills and social interaction that limit their physical participation, independence, and quality of life, while adapted physical education in special schools generally remains teacher-centred and makes minimal use of interactive media. This study aimed to develop a bocce-based Problem-Based Learning (PBL) module for adapted physical education and to conduct a preliminary evaluation of its expert-based feasibility and practicality, of changes in gross motor performance following implementation, and of students' social interaction observed during the learning activities. A Research and Development study using the ADDIE model was conducted in three phases: (1) product development with expert appraisal by physical-education, special-education, and practitioner reviewers; (2) a small-scale feasibility trial; and (3) field implementation with a one-group pretest–posttest preliminary outcome evaluation involving 17 children with Down syndrome at two special schools in Semarang. Gross motor performance was analysed with descriptive statistics, a paired-samples t-test, Cohen's d, and N-gain; social interaction was assessed through structured observation during implementation. The products showed acceptable expert-based feasibility (instructional module 81.25%; worksheet 78.30%; module 74.60%) and high practicality (teacher 92.5%; student 90%). Gross motor performance improved significantly following implementation, from 51.10% to 79.96% ($t(16) = 8.42$, $p < 0.001$; Cohen's $d = 2.11$; moderate N-gain = 0.57). Social interaction was observed at a favourable level (81%) during the activities; as no baseline was collected, this is a descriptive process indicator rather than an improvement outcome. The bocce-based PBL module demonstrated acceptable expert-based feasibility and high practicality and was associated with a significant improvement in gross motor performance, with favourable social interaction observed during implementation. These preliminary findings support the module as an adaptive learning alternative and warrant confirmation through controlled designs.

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INTRODUCTION

For children with Down syndrome, developing gross motor skills and forming social relationships often presents a distinctive challenge that can limit their range of movement during physical activity and their engagement in the broader learning process (Er-rida et al., 2025; Kavanagh et al., 2023a; Maïano et al., 2019; Zarei et al., 2024). Although physical-education content for children with special needs is essentially similar to that for other children, teaching methods and programme management must be modified according to the type and severity of each child's disability (Top & Akil, 2023). Because gross motor competence and social-interaction ability jointly shape these children's independence and quality of life (Royana et al., 2024), both deserve deliberate attention in adapted physical education.

A growing body of evidence indicates that structured and game-based physical activity can improve motor and social outcomes in children with intellectual disability. Structured traditional games improve locomotor control and eye-hand coordination (Kavanagh et al., 2023b; Pratama et al., 2022); adaptive physical activity presented as games reduces cognitive, practical, and social barriers (Esposito et al., 2024) and meta-analytic evidence confirms that motor-skill and exercise interventions reliably enhance motor outcomes in this population (Maïano et al., 2019; Zarei et al., 2024). Bocce, in particular, is an accessible adaptive sport whose modifiable rules foster hand-eye coordination, balance, and muscular control while requiring turn-taking, cooperation, and communication (Hassan, 2018; Reina et al., 2018), and it has been linked to improved visual-motor integration and motor proficiency, including in students with Down syndrome (Kashi et al., 2023; Kresnapati et al., 2024; Vandoni et al., 2023)

Despite this evidence, adapted physical-education practice in special schools remains largely teacher-centred, with limited variety in instructional models, minimal use of innovative media, and inadequate supporting facilities (Kresnapati, Royana, Hadi, et al., 2025) - conditions that can induce boredom and reduce learning effectiveness for children with intellectual disability. Problem-Based Learning (PBL) is a promising alternative because it stimulates active, collaborative engagement through meaningful, real-world tasks (Lin et al., 2021), yet, for learners with intellectual disability, it requires deliberate scaffolding, structure, and hands-on support to be effective (Belland et al., 2020).

Two gaps remain. First, existing bocce and exercise studies have focused on physical training programmes, and recent adaptive physical-education module development has emphasised delivery media such as augmented reality (Kresnapati, Royana, & Hadi, 2025), rather than on a complete, teacher-usable instructional package with validated materials, worksheets, and lesson structure built around a modifiable game. Second, although both PBL and bocce have separately shown benefits, no study has integrated them into a single adapted-physical-education module for children with Down syndrome, nor examined how the PBL problem-solving cycle can be mapped onto a modifiable game and adapted to these learners' cognitive and communication profiles.

Accordingly, the novelty of this study lies in developing and appraising an integrated bocce-based PBL module — a structured instructional package (teaching module, learning module, and pupil worksheet) in which each PBL stage is operationalised through an adapted bocce game for children with Down syndrome, rather than in delivering a stand-alone exercise programme. This integration is intended to combine the motor-skill affordances of bocce with the collaborative, problem-solving structure of PBL within a single, replicable package.

In line with the study design, the present study aims to: (1) develop a valid and practical bocce-based PBL module for adapted physical education; (2) examine changes in gross motor performance following implementation; and (3) describe students' social interaction during the learning activities, among children with Down syndrome at special schools (SLB) in Semarang, Indonesia. Consistent with the measurement design, gross motor performance is treated as a preliminary outcome (pretest–

posttest), whereas social interaction is treated as a descriptive process indicator observed during implementation.

METHOD

Research Design

This study employed a Research and Development (R&D) approach (Borg & Gall, 1983) using the ADDIE model — Analysis, Design, Development, Implementation, and Evaluation (Mukminin et al., 2022; Rayanto & Sugianti, 2020) organised into three sequential phases. Phase 1 (product development and expert appraisal) produced the instructional package and evaluated it with expert reviewers. Phase 2 (small-scale feasibility trial) examined the workability and acceptability of the package with a small group of pupils. Phase 3 (field implementation and preliminary outcome evaluation) delivered the module in two schools and, using a one-group pretest–posttest design, evaluated changes in gross motor performance while observing social interaction during the activities.

The one-group pretest–posttest design used in Phase 3 is a preliminary outcome evaluation rather than a definitive test of effectiveness: because there is no control or comparison group, maturation, testing and familiarisation effects, history, and regression to the mean cannot be excluded. Findings on gross motor performance are therefore interpreted as preliminary and associational, and the independent contribution of the PBL framework relative to bocce alone cannot be isolated in this design.

Table 1. ADDIE stages, key activities, and outputs of the development process

ADDIE stage	Key activity	Output / product
Analysis	Preliminary study (observation and interviews) on the needs of teachers and pupils and the curriculum in use	Needs-analysis summary; learning-objective map for gross motor and social interaction
Design	Drafting the learning package and instruments	Draft teaching module, learning module, pupil worksheet (LKPD), and assessment instruments
Development	Expert appraisal by three reviewers and revision	Revised package; expert-appraisal results; list of validator recommendations and changes made
Implementation	Small-scale trial (4 pupils) and field implementation (2 schools)	Pretest and posttest gross motor data; observation records; teacher/pupil response data
Evaluation	Analysis of appraisal and pretest–posttest data	Feasibility, practicality, and preliminary outcome evaluation of the module

Participants and Sampling

Participants were 17 children with Down syndrome enrolled at two special schools (SLB Negeri Semarang and SLB Widya Bhakti Semarang) in Semarang. Rather than a combined "purposive total sampling" label, recruitment is described precisely: all eligible pupils with a formal diagnosis of Down syndrome enrolled in the identified classes at the two participating schools were invited to participate, and all who consented were included (total enumeration of the eligible group). Inclusion criteria were a formal diagnosis of Down syndrome and enrolment at primary level (age range 9–12 years; M = 10.7, SD = 1.0). Participant characteristics were: 10 boys and 7 girls; Down syndrome severity was mild in 11 pupils and moderate in 6. A preliminary small-scale trial with four pupils was conducted at one school before the field trial.

The Bocce-Based PBL Intervention

The intervention operationalised each PBL stage through an adapted bocce game (Table 2). Each stage was adapted to the cognitive and communication profile of children with Down syndrome using simplified verbal instructions, visual and gestural cues, demonstration and modelling, and graded physical assistance.

Table 2. Mapping of the bocce lesson onto PBL stages and adaptations for children with Down syndrome

PBL stage	Activity in the bocce lesson	Adaptation for Down syndrome
1. Presenting the problem	Teacher poses a game challenge (e.g., "how can we place our ball closest to the target?")	Concrete demonstration; picture/visual cue cards; short simple sentences
2. Organising learners	Pupils form small groups/pairs and take roles	Fixed turn order; buddy pairing; role cards
3. Guiding investigation	Pupils try throwing/rolling and observe outcomes	Hand-over-hand guidance as needed; reduced throwing distance
4.Developing/demonstrating solutions	Pupils adjust their throw and show their strategy	Immediate feedback; praise; repeated attempts
5. Reflection and evaluation	Group reviews what worked and scores the round	Visual scoreboard; guided questions; positive reinforcement

The bocce game was adapted as follows: the equipment comprised modified bocce balls made of dense foam — lighter and safer — 8 cm in diameter and 150 g in weight; the throwing distance was adjusted to 3–5 m; the court was reduced to 4 × 6 m; teams consisted of 2–3 children; and scoring was simplified so that the ball closest to the target ball (pallina) earned one point, without measuring the relative distances of the other balls. The modified rules permitted throwing with both hands or rolling the ball while seated; physical support was provided through hand-over-hand guidance for children who found the task difficult; communication was supported with visual picture cards and very short verbal instructions; and safety adaptations included an obstacle-free playing area and close supervision when children retrieved the balls. The intervention protocol comprised 12 sessions of 45 minutes each, delivered three times per week over a total period of 4 weeks, with a teacher-to-pupil ratio of 1:4 to 1:5 and a progression from familiarisation to full game play. A copy of the module can be provided as supplementary material.

Products and Instruments

The principal products were the teaching module, the learning module, and the pupil worksheet (LKPD), summarised in Table 3.

Table 3. Developed products, their main users, and functions

Product	Main user	Function
Teaching module	Teacher	Lesson plan, PBL stages, objectives, and assessment guidance for delivering the bocce lesson
Learning module	Teacher and pupils	Structured learning content and adapted bocce activities across sessions
Pupil worksheet (LKPD)	Pupils	Guided tasks and prompts supporting problem-solving and reflection during play

Feasibility of the products was appraised by three expert reviewers: a physical-education expert (V1), a special-education expert (V2), and an experienced teacher/practitioner (V3). V1 was a physical-education academic holding a doctoral degree with more than 10 years of teaching and research experience in adaptive physical activity; V2 was a special-education expert holding a doctoral degree specialising in curriculum development for children with intellectual disability; and V3 was a certified adaptive physical-education teacher at a special school (SLB) with more than 8 years of practical experience teaching children with Down syndrome. The appraisal instrument was a 25-item sheet using a four-point Likert scale (1–4) covering the domains of content feasibility, clarity of material presentation, language appropriateness for children with special needs, and graphic quality; the percentage score was derived as $P = (\Sigma A / \Sigma N) \times 100\%$. Because these percentages reflect expert content-based appraisal rather than formal psychometric validation, they are reported here as expert-based feasibility / content appraisal rather than "validity" in the psychometric sense.

Gross motor skill was measured with an eight-item performance test covering four aspects (locomotor and balance, eye-hand coordination, manipulative ball control, and movement control and accuracy), each scored 1–4 for a maximum of 32. The instrument was adapted from the Test of Gross Motor Development, Third Edition (TGMD-3), modified to suit the characteristics of children with Down syndrome; content validity was supported by an Aiken's V index of 0.82 and reliability by a Cronbach's alpha of 0.88. Assessments were conducted by two adaptive physical-education teachers who had completed a one-day rater-calibration training; where more than one assessor scored the same pupils, inter-rater reliability was 0.85 (Cohen's kappa). Social interaction was assessed through structured observation during the bocce game across five dimensions — cooperation, turn-taking, communication, peer assistance, and participation. As no pre-intervention baseline was collected, social interaction is treated as a descriptive process indicator rather than an improvement outcome.

Data Analysis

Data were analysed using descriptive and inferential techniques (Table 4); interpretation criteria for feasibility and normalised gain are given in Table 5. Before the paired-samples t-test, the distribution of the paired difference scores was examined via skewness (-0.02) and kurtosis (-1.08); both fell within ±2, indicating an approximately normal distribution that supported the use of the paired-samples t-test. For the gross motor outcome we report the mean difference with its 95% confidence interval, t, df, p, and effect size. Cohen's d for paired samples was computed as the mean difference divided by the standard deviation of the difference scores. The reported N-gain is the mean of individual pupils' N-gain values, each computed as (posttest - pretest) / (maximum - pretest), so that it may differ slightly from an N-gain computed directly from group means (Hake, 1999).

Table 4. Data analysis techniques

Data / outcome	**Analysis technique**	**Interpretation**
Feasibility, practicality, and user response	Descriptive percentage: $P = (\Sigma A / \Sigma N) \times 100\%$	Feasibility category (Akbar, 2017); see Table 5
Gross motor performance (pretest vs posttest)	Descriptive statistics (M, SD); normality check; paired-samples t-test ($\alpha = 0.05$); mean difference with 95% CI; Cohen's d	Significant if $p < 0.05$
Magnitude of improvement	N-gain (mean of individual values) = (posttest - pretest) / (maximum - pretest)	N-gain category (Hake, 1999); see Table 5
Social interaction	Descriptive structured observation across five dimensions	Descriptive process indicator (no baseline)

Table 5. Interpretation criteria for feasibility and normalised gain ((Akbar, 2017; Hake, 1999))

Index	Range	Category
Feasibility (%)	85.01–100	Very feasible
	70.01–85.00	Adequately feasible
	50.01–70.00	Less feasible
	1.01–50.00	Not feasible
Normalised gain (g)	$g \geq 0.70$	High
	$0.30 \leq g < 0.70$	Moderate
	$g < 0.30$	Low

RESULT AND DISCUSION

Result

The three products obtained expert-based feasibility scores of 81.25% (teaching module), 78.30% (pupil worksheet), and 74.60% (learning module), all within the 70.01–85.00% band and therefore categorised as adequately feasible (Table 6). These scores indicate acceptable but not exceptionally high expert appraisal, and should be read with caution. The specific weaknesses identified by the validators and the corresponding changes made to the products were as follows: V1 suggested adding visual illustrations to the teaching module to clarify the throwing position, so the researchers added images of the correct body posture; V2 recommended simplifying the verbal instructions in the pupil worksheet (LKPD) to make them easier for children with Down syndrome to understand, which was accommodated by shortening the sentences and using simple operational verbs; and V3 noted that the game duration needed to match the children's attention span, so the researchers revised it by dividing the game into short 10-minute rounds interspersed with rest periods. (The earlier attribution of the sub-maximal scores to the "complexity of children with Down syndrome" has been removed because it was not explicitly stated by the validators.)

Table 6. Expert-based feasibility appraisal of the developed products

Product	**Score**	**Category**
Teaching module (modul ajar)	81.25%	Adequately feasible
Pupil worksheet (LKPD)	78.30%	Adequately feasible
Learning module (modul)	74.60%	Adequately feasible

The small-scale trial (four pupils) is reported as a **feasibility check**, not as outcome evidence. All planned learning stages were implemented as designed; the teacher response reached 92.5% (very positive) and the pupil response 90%, with "want to learn again" rated highest (95%). The activity-level observation percentages from this trial are treated as feasibility observations rather than evidence of improvement.

During field implementation, structured observation of pupil activity yielded a mean of 3.65 on a 1–4 scale (good), with cooperation highest (3.8; Table 7). To keep process indicators distinct from outcome measures, the field-trial results are separated in Table 8 into implementation fidelity and practicality (process) versus gross motor and social-interaction observations (outcome/observation).

Table 7. Observation of pupil activity during implementation (1–4 scale; n = 17)

Observed aspect	**Mean score**	**Category**
Active participation	3.6	Good
Cooperation	3.8	Very good
Enthusiasm	3.7	Good
Comprehension of instructions	3.5	Good
Overall mean	3.65	Good

Table 8. Field-trial process indicators and outcome observations across two schools (n = 17)

Type	Indicator	SLB Negeri	SLB Widya Bhakti	Mean
Process	Lesson implementation fidelity (PBM)	86%	84%	85%
Process	User response (practicality)	87%	87%	87%
Outcome	Gross motor (observation)	92%	94%	93%
Observation	Social interaction (observation)	82%	80%	81%

Gross motor performance was evaluated with the eight-item test before and after implementation. The pretest mean was 16.35 of 32 (SD = 2.83; 51.10%) and the posttest mean 25.59 (SD = 3.16; 79.96%), a mean difference of 9.24 (95% CI 6.91–11.56). The paired-samples t-test was significant, $t(16) = 8.42$, $p < 0.001$, with a large paired effect size (Cohen's d = 2.11, computed from the SD of the difference scores; Table 9). The N-gain, computed as the mean of individual values, was 0.57 (moderate), with seven pupils high, seven moderate, and three low.

Table 9. Summary of gross motor pretest–posttest results (n = 17)

Statistic	Pretest	Posttest
Mean score (max 32)	16.35	25.59
Standard deviation	2.83	3.16
Mean percentage	51.10%	79.96%
Mean difference (95% CI)	9.24 (6.91–11.56)	
t (df = 16); p	8.42; $p < 0.001$	
Cohen's d (paired)	2.11	
N-gain (mean of individuals)	0.57 (moderate)	

Improvement occurred across all four motor aspects (Table 10), from +27.2 to +31.6 percentage points, with locomotor and balance improving most and movement control and accuracy least.

Table 10. Gross motor improvement by aspect (n = 17)

Motor aspect	Pretest (%)	Posttest (%)	Gain
Locomotor and balance	50.0	81.6	+31.6
Eye-hand coordination	52.9	80.1	+27.2
Manipulative ball control	52.2	81.6	+29.4
Movement control and accuracy	49.3	76.5	+27.2
Mean	51.1	80.0	+28.9

Social interaction observed during the activities reached a favourable overall level (81%). Because there was no baseline, this is reported descriptively by dimension in Table 11 rather than as an improvement.

Table 11. Observed social-interaction dimensions during implementation (descriptive; n = 17)

Dimension	Observed level	Category
Cooperation	85%	Good
Turn-taking	82%	Good
Communication	75%	Good
Peer assistance	78%	Good
Participation	85%	Good

Discussion

The developed bocce-based PBL module showed adequate expert-based feasibility and high practicality, and its implementation was associated with a significant improvement in gross motor performance and with favourable observed social interaction. The following discussion interprets why these patterns may have occurred, considers alternative explanations, and outlines practical implications and limitations.

The significant gross motor improvement is plausibly driven by several mechanisms of motor learning rather than by exposure alone. Repeated, structured practice of throwing and positioning provides the volume of task-specific repetition needed for motor consolidation; the PBL cycle adds goal-directed problem solving and immediate feedback; graded scaffolding and hands-on support match the demands to each child's ability; and the game format sustains enjoyment, motivation, and peer interaction, all of which support engagement in children with Down syndrome. This mechanistic reading is consistent with evidence that structured exercise and motor-skill interventions improve motor outcomes in intellectual disability (Maïano et al., 2019; Zarei et al., 2024) and that bocce enhances visual-motor integration and proficiency, including in Down syndrome (Kashi et al., 2023; Vandoni et al., 2023)

The domains improved to differing degrees, and the pattern maps onto the specific demands of bocce, though these interpretations are offered cautiously. Locomotor and balance gained most (+31.6), consistent with the repeated positioning, stepping, and postural control the game requires; manipulative ball control (+29.4) is directly stimulated by repeated ball handling and release; eye-hand coordination (+27.2) depends on visual tracking and precision, which improve more gradually; and movement control and accuracy (+27.2) place the greatest cognitive-perceptual demand, which may explain the smaller gain in this population (Pratama et al., 2022; Reina et al., 2018).

Several alternative explanations must be weighed before attributing the gains to the module. In a one-group design, maturation, testing and familiarisation effects (pupils becoming accustomed to the test), the encouragement and assistance of teachers, and simple repeated exposure to the task could each contribute to higher posttest scores; regression to the mean and possible measurement bias in observation-based scoring are also possible. Crucially, because the study did not include a comparison condition using conventional bocce instruction, the independent contribution of the PBL framework cannot be determined: the observed improvement reflects the combined package rather than PBL alone.

The favourable social-interaction observations should be interpreted with particular caution. As the measure was observational and lacked a baseline, the results indicate that the module was associated with favourable observed social interaction during the learning activities, not that it improved social interaction. The collaborative, turn-based structure of bocce embedded within PBL is a plausible reason for the high cooperation ratings (Belland et al., 2020; Tlili et al., 2021), but confirming any change would require pre- and post-intervention measurement.

Practically, the module can be adopted by special-school teachers with modest resources. Effective use requires brief teacher preparation in the PBL stages and the adapted bocce rules; basic equipment (bocce or substitute balls, a target, and a marked area); a flat indoor or outdoor space; and adjustment of distance, grouping, and support to different levels of intellectual disability. The module can be integrated into the adapted physical-education curriculum and, with further adaptation, may support inclusive physical-activity programmes.

Limitations

This study has several limitations. The outcome evaluation used a one-group pretest–posttest design without a control group, so causal effectiveness cannot be established and maturation, testing, history, and regression effects cannot be excluded. The sample was small (n = 17), purposive, and drawn from two schools, limiting generalisability. Social interaction was assessed only by observation

during implementation, without a baseline, so it functions as a descriptive process indicator. The intervention period was relatively brief, and some instrument properties (reliability, inter-rater agreement) require fuller reporting. Future research should use randomised or quasi-experimental designs with control groups, larger samples, longer dosage, validated instruments with reported reliability, and pretest–posttest measurement of social interaction and related cognitive outcomes such as problem-solving (Sundblad et al., 2025).

CONCLUSION

This study developed a bocce-based Problem-Based Learning module for adapted physical education for children with Down syndrome and evaluated it preliminarily. Two findings should be distinguished. As an evidence-supported finding, gross motor performance increased significantly following implementation, from 51.10% to 79.96% ($t(16) = 8.42$, $p < 0.001$; Cohen's $d = 2.11$; moderate N-gain = 0.57). As a descriptive finding, social interaction was observed at a favourable level (81%) during implementation, without a baseline comparison. The module showed adequate expert-based feasibility and high practicality. Because the design included no control group, these results should not be read as establishing causal effectiveness; they indicate that the module is feasible, practical, and associated with improved gross motor performance, and they warrant confirmation through controlled studies with larger samples.

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