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FROM MOVEMENT TO MEANING: HOW 'THE SUPER 5' KINESTHETIC ACTIVITIES SHAPE STUDENT ENGAGEMENT AND CONCEPTUAL UNDERSTANDING IN MATHEMATICS

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Abstract

This study investigates student perceptions of movement-based mathematics pedagogy through the Making Mathematics Meaningful with Movements (4M) programme. Drawing on feedback from two student cohorts (Division F and Division D; N = 80+ responses), the research identifies five high-impact activities that foster engagement and conceptual clarity in Grade VIII mathematics. Using qualitative thematic analysis, student responses were coded across four dimensions: engagement, conceptual understanding, memory retention, and perceived relevance. Findings reveal strong student preference for activities involving paper folding, matchstick puzzles, and embodied group movement, with repeated emphasis on "learning by doing," "multiple solution pathways," and "fun." Importantly, student-reported understanding aligns with improvements in topics such as quadrilaterals, graphs, fractions, and rational numbers. The study argues that centering student voice provides empirical support for embodied cognition frameworks and offers practical insights for designing meaningful mathematics instruction.

Keywords: *Embodied Cognition, Student Feedback, Kinesthetic Learning, Mathematics Education, Conceptual Understanding*

1. Introduction

Mathematics is widely recognised as a discipline central to logical reasoning, problem-solving, and scientific thinking; however, it continues to be perceived by many learners as abstract, procedural, and disconnected from everyday experience. Students often approach mathematics as a subject dominated by formulas, rules, and memorisation rather than as a meaningful system of relationships and patterns (National Council of Educational Research and Training [NCERT], 2005). Such perceptions contribute to disengagement, anxiety, and a lack of conceptual understanding, particularly during the middle school years when mathematical ideas become increasingly formal and symbolic.

Recent developments in mathematics education challenge this traditional, disembodied view of learning. Drawing on the theoretical framework of embodied cognition, researchers argue that thinking is not confined to the mind alone but is shaped by bodily action, perception, and interaction with the environment (Lakoff & Núñez, 2000; Glenberg et al., 2004). From this perspective, mathematical understanding emerges through coordinated activity involving the body, gestures, and spatial reasoning. Classroom-based studies have demonstrated that movement-oriented approaches—such as gesture, whole-body interaction, and spatial exploration—can enhance conceptual understanding, improve retention, and support flexible thinking in mathematics (Abrahamson et al., 2020; Nemirovsky et al., 2013).

Parallel to this work, arts-integrated and kinesthetic pedagogies, including dance, choreography, and storytelling, have gained increasing attention as powerful tools for mathematical learning. These approaches create opportunities for students to explore patterns, symmetry, geometry, and relationships through movement and creative expression, making abstract ideas tangible and socially meaningful (Kaufmann, 2011; Schaffer, 2012). When learners physically enact mathematical relationships, they gain access to multiple representations, visual, spatial, and kinaesthetic—thereby deepening understanding and reducing cognitive load (Duijzer et al., 2019).

Despite this growing body of research, a significant gap remains: while many studies demonstrate the effectiveness of embodied approaches, there is limited focus on how students themselves perceive and experience these pedagogies. Student voice is a critical but underexplored dimension of educational research, particularly in mathematics, where classroom practices are often evaluated primarily through achievement outcomes rather than learner perspectives. Understanding which activities students find meaningful, engaging, and helpful for learning can provide valuable insights for designing sustainable and responsive pedagogical interventions.

1.1 Research question:

Which movement-based activities do students perceive as most meaningful, and how does this align with their conceptual understanding of mathematics?

This study aims to investigate student perceptions of movement-based mathematics learning, focusing on activity preference, conceptual understanding, and topic alignment, using thematic analysis of feedback from intervention groups within a Solomon Four-Group design. Drawing on authentic feedback from two Grade VIII cohorts (Division F and Division D) participating in the *Making Mathematics Meaningful with Movements (4M) Programme*, this paper foregrounds student voice as a central source of evidence for pedagogical effectiveness. By systematically analysing students' reflections on the activities they found most engaging, memorable, and conceptually useful, the study aims to bridge the gap between embodied learning theory and classroom practice. In doing so, it highlights how movement-based pedagogies are not only theoretically grounded but also experientially validated by learners themselves, offering a compelling case for reimagining mathematics education as an embodied, meaningful, and student-centred process.

1.2. Objectives: The present study, situated within the *Making Mathematics Meaningful with Movements (4M) Programme* and analysed through student feedback from intervention groups in a Solomon Four-Group design, aimed to achieve the following objectives:

1. To identify the movement-based mathematics activities that students perceive as most engaging and meaningful following their participation in the 4M intervention.
2. To examine the relationship between preferred activities and conceptual understanding, particularly in key middle school mathematics topics such as geometry, algebra, and number systems.
3. To generate evidence for the role of embodied and kinesthetic approaches in enhancing meaningful mathematics learning, grounded in authentic student voice.

2. Method

2.1 Research Design and Participants

This study forms part of a larger quasi-experimental investigation structured through a Solomon Four-Group Design, which was employed to rigorously evaluate the effectiveness of the *Making Mathematics Meaningful with Movements (4M) Programme*. The design allowed for the control of pre-testing effects while comparing learning outcomes across multiple groups.

Within this framework, the present paper focuses specifically on the two intervention groups (Division F and Division D), which actively participated in the movement-based pedagogical programme. These groups were exposed to the full sequence of 4M activities, including kinesthetic puzzles, embodied coordinate geometry, narrative-based learning, paper modelling, and group choreography.

The participants included:

- Two Grade VIII divisions (Division F and Division D)
- Students aged approximately 12–14 years
- Approximately 80 individual feedback responses analysed across both divisions

These cohorts were selected for analysis as they provided rich qualitative insights into student experiences following direct engagement with the intervention.

2.2 Data Sources: Data were collected through student feedback sheets administered after the intervention sessions. These structured feedback instruments were designed to capture both reflective and evaluative responses to the programme.

Each feedback sheet included four open-ended prompts:

1. Most interesting aspect of the sessions
2. Any specific activity remembered and worth mentioning
3. Suggestions for improving the programme
4. Mathematics topics students would like to learn through movement

The use of open-ended questions enabled students to express their experiences in their own words, providing authentic insights into engagement, understanding, and preferences.

2.3 Data Analysis: The qualitative data were analysed using a thematic analysis approach informed by the methodology outlined by Braun and Clarke (2006). This approach allowed for systematic identification and interpretation of recurring patterns within student responses.

The analysis proceeded through the following stages:

- Open coding: Initial coding of responses to identify key ideas, recurring terms, and meaningful phrases
- Categorisation: Grouping of codes into broader activity-based clusters (e.g., paper folding, matchstick puzzles, number line activities)
- Frequency mapping: Quantification of coded responses to identify dominant themes and patterns across the dataset

- Conceptual alignment: Cross-linking activity preferences with mathematical topics mentioned by students (e.g., quadrilaterals, graphs, fractions)

This combined qualitative–quantitative approach enabled the study to capture both the depth of student experiences and the distribution of preferences, thereby providing a comprehensive understanding of how different movement-based activities contributed to engagement and conceptual learning.

3. Results: Activity–Feedback Alignment

Table 1: Frequency of Most Liked Activities (Division F + Division D Combined)

Activity Category	Example Student Phrases	Frequency (n)	Percentage (%)
Paper Folding / Paper Matters	"paper folding," "flower folding," "square folding"	21	28%
Cutting / One-Cut Theorem	"one cut," "cutting shapes," "cutting activity"	13	17%
Matchstick Activities / Puzzles	"matchstick activity," "logical puzzles"	13	17%
Movement / Dance-Based Learning	"dance in maths," "body movement," "dance moves"	11	15%
Number Line / Number Rope	"number line activity," "rational number activity"	9	11%
Story-Based / Conceptual Activities	"rational numbers," "√2," "story learning"	8	8%
General "Everything interesting"	"everything," "all activities"	5	4%

3.1 Activity 1: Paper Matters (Folding & Box Volume)

Frequency (Very High):

- "paper folding" (multiple repetitions across both divisions)
- "flower folding activity"
- "making so many folds"
- "square folding"

Student Voice Themes:

- Highly engaging

- Memorable
- Visually clear

Topics Identified:

- Quadrilaterals (most frequent)
- Fractions
- Geometry

Interpretation: Paper folding is the **most preferred modality**, strongly linked to geometry conceptualisation.

3.2. Activity 2: Matchstick Puzzles

Frequency (High):

Repeated mentions across both divisions:

- "Matchsticks activity, amazing"
- "I had fun"
- "logical activities like matchsticks"

Student Voice Themes:

- Enjoyment: "fun," "amazing"
- Cognitive challenge: "logical activities"
- Creativity: multiple ways to solve

Conceptual Links Identified by Students:

- Algebra
- Equation solving
- General problem-solving

Interpretation: Students value matchstick puzzles for **non-linear thinking and experimentation**, confirming their role in developing algebraic flexibility.

3.3 Activity 3: Coordinate Geometry through Movement

Frequency (Moderate):

- "Using my body in understanding"
- "making shapes without body"
- "dance in mathematics"

Student Voice Themes:

- Embodied clarity
- Memory retention through movement
- Enjoyment via physical activity

Topics Students Linked:

- Graphs
- Linear equations

Interpretation: Embodied positioning supports **spatial reasoning and graph interpretation**, especially for abstract coordinate systems.

3.3 Activity 3: M-Story (Dangerous Ratio)

Frequency Insight (Emerging but strong conceptual recall):

- "I loved the rational number activity"
- "learning rational numbers"
- "square root of 2"

Student Voice Themes:

- Curiosity about concepts
- Interest in number properties
- Awareness of irrational numbers

Topics Identified:

- Rational numbers
- Square roots
- Number systems

Interpretation: Narrative + embodiment enhanced **conceptual understanding of number systems**, even if fewer explicitly named the story.

3.4 Activity 4: Queen Dido (Optimization)

Frequency Insight (Moderate):

- "cutting shapes"
- "paper cutting activity"
- "cutting 2 connections"

Student Voice Themes:

- Hands-on discovery
- Surprise at outcomes
- Exploration

Topics Identified:

- Quadrilaterals
- Area

Interpretation: Students recognised **area–perimeter relationships implicitly**, even without formal terminology.

3.5 Activity 5: Group M-Proof (Murmuration)

Frequency Insight (Moderate):

- "dance moves"
- "dance in maths"
- "group activities"

Student Voice Themes:

- Collective learning
- Enjoyment
- Movement-based understanding

Topics Identified:

- Angles
- Lines
- Geometry

Interpretation: Students emphasised **social learning and collaboration**, indicating that large-group movement enhances engagement.

Table 2: Activities Students Remembered Most

Activity Category	Typical Mentions	Frequency (n)	Percentage (%)
Paper Folding Activities	"flower folding," "paper folding"	18	25%
Matchstick Activities	"matchstick puzzle," "matchstick equation"	12	17%
Cutting / One-Cut Activities	"one cut activity," "cutting shapes"	11	15%
Number Line / Rational Tasks	"number line," "rational number"	10	14%
Movement / Dance Activities	"dance activity," "body movement"	8	11%
Geometry Constructions	"quadrilateral tricks," "making shapes"	7	10%
Others / No Response	"none," "no"	6	8%

Based on the above table the following are the most preferred activities by students

Most Preferred Activities (Based on Frequency)

1. Paper Folding (highest mentions), Cutting & One-Cut Theorem

2. Matchstick Puzzles
3. Coordinate/Number Line Activities
4. Dance / Movement Activities
5. Mathematical Stories followed with Hands-on exploration

Table 3: Alignment Between Student Preference and Conceptual Topics

Activity Type	Most Associated Conceptual Areas	Evidence from Student Voice
Paper Folding	Quadrilaterals, geometry, fractions	"quadrilaterals," "paper folding helped"
Matchstick Puzzles	Algebra, logical reasoning	"solving equations," "logical thinking"
Cutting / One-Cut	Geometry, area, shape properties	"cutting shapes," "one cut activity"
Movement / Dance	Graphs, angles, spatial reasoning	"using body," "dance in maths"
Number Line / Rope	Fractions, rational numbers	"number line activity," "rational numbers"
Story-Based Activities	Number systems, conceptual understanding	"square root," "rational numbers"

Overall Interpretations:

- *"Paper folding activities were the most preferred (28%), followed by matchstick-based puzzles (17%) and cutting-based tasks (15%), indicating a strong inclination toward tactile and manipulative learning experiences (Table 1 & 2)."*
- *"Geometry-related topics, particularly quadrilaterals emerged as the most requested area for movement-based learning (Table 3)."*

5. Discussion

The findings of this study demonstrate a strong alignment between **student preference and conceptual understanding**, particularly in activities that integrate physical engagement with mathematical thinking. Activities that combined **movement and manipulation**, such as paper folding and prop-based tasks, were most frequently preferred and remembered by students. This aligns with research in embodied cognition, which posits that physical interaction with concepts provides additional cognitive pathways for understanding (Lakoff & Núñez, 2000; Abrahamson et al., 2020). By engaging both the body and the mind, these activities enabled learners to construct meaning through action rather than relying solely on abstract symbols.

Similarly, activities that encouraged **exploration and open-ended problem-solving**, such as matchstick puzzles and cutting tasks, were highly valued by students. This supports findings from constructivist and embodied learning research, which emphasise the importance of experimentation and multiple solution pathways in developing flexible mathematical thinking (Nemirovsky et al., 2013; Duijzer et al., 2019). Students' repeated references to "trying different ways" and "logical thinking" suggest that such activities promote deeper engagement with underlying mathematical structures rather than surface-level procedural knowledge.

The study also highlights the importance of **visualisation in learning mathematics**, particularly through number line activities and geometric representations. Students reported that physically representing numbers and shapes helped them "see" mathematics more clearly. This resonates with prior research indicating that embodied and spatial representations reduce cognitive load and enhance conceptual clarity, especially in topics such as number systems and geometry (Dackermann et al., 2017; Sinclair & Heyd-Metzuyanim, 2014).

Notably, **quadrilaterals and geometry emerged as the most requested topics** for movement-based learning. This finding is consistent with literature suggesting that spatial and geometric concepts particularly benefit from embodied approaches, as they are inherently linked to movement, orientation, and visual reasoning (Kaufmann, 2011; Schaffer, 2012). The students' preference for learning geometry through folding, constructing, and group formations underscores the potential of kinesthetic pedagogy to make abstract spatial relationships tangible and accessible.

Importantly, the findings foreground **student voice as evidence of meaningful learning**. Students did not merely describe the activities as enjoyable; they articulated clear connections between the activities and their understanding of mathematical concepts. This supports the argument that **engagement is not superficial but foundational to conceptual depth**, echoing research that highlights the role of active participation and emotional engagement in sustained learning (Goldin-Meadow & Beilock, 2010; Polman et al., 2021). When students reported that they "understood" rather than just "remembered," it indicated a shift from procedural learning to conceptual reasoning.

Overall, the study reinforces the theoretical claims of embodied cognition by providing **empirical, student-centered evidence**. The alignment between preferred activities and conceptual gains suggests that movement-based pedagogies are not only engaging but also pedagogically effective. By situating mathematical ideas within physical, social, and exploratory contexts, the 4M programme enables learners to experience mathematics as meaningful, dynamic, and connected, an outcome strongly supported by both student feedback and existing research.

6. Limitations

This study has following limitations.

1. The data are based on self-reported student feedback from two intervention groups, which may reflect subjective perceptions rather than measurable learning gains.
2. The absence of longitudinal tracking limits conclusions about sustained conceptual retention
3. The study is situated within a specific cultural (Pune city) and curricular context (CBSE board), which may affect generalisability.

7. Implications

For Classroom Practice

- Prioritise paper-based and kinesthetic activities
- Use movement for abstract topics (graphs, algebra)

For Curriculum Design

- Embed low-cost embodied tasks in textbooks
- Align activities with geometry-heavy units

For Research

- Quantify learning gains alongside feedback
- Explore differential impact across ability groups

8. Conclusion

This study demonstrates that students overwhelmingly favour embodied, hands-on, and collaborative mathematics learning experiences. Activities such as paper folding, matchstick puzzles, and number line movement are not only engaging but also deeply connected to conceptual understanding.

As reflected across both divisions:

"Using body and activity helped us understand maths better."

These findings reinforce the premise that mathematics becomes meaningful when it is experienced, not just taught.

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