

# Elicitation of Multimodal Mathematical Reasoning in Balinese Dance Through Verbal and Non-Verbal Justification

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## Research Question

*How do students develop multimodal mathematical reasoning through verbal and non verbal justification in Balinese dance?*

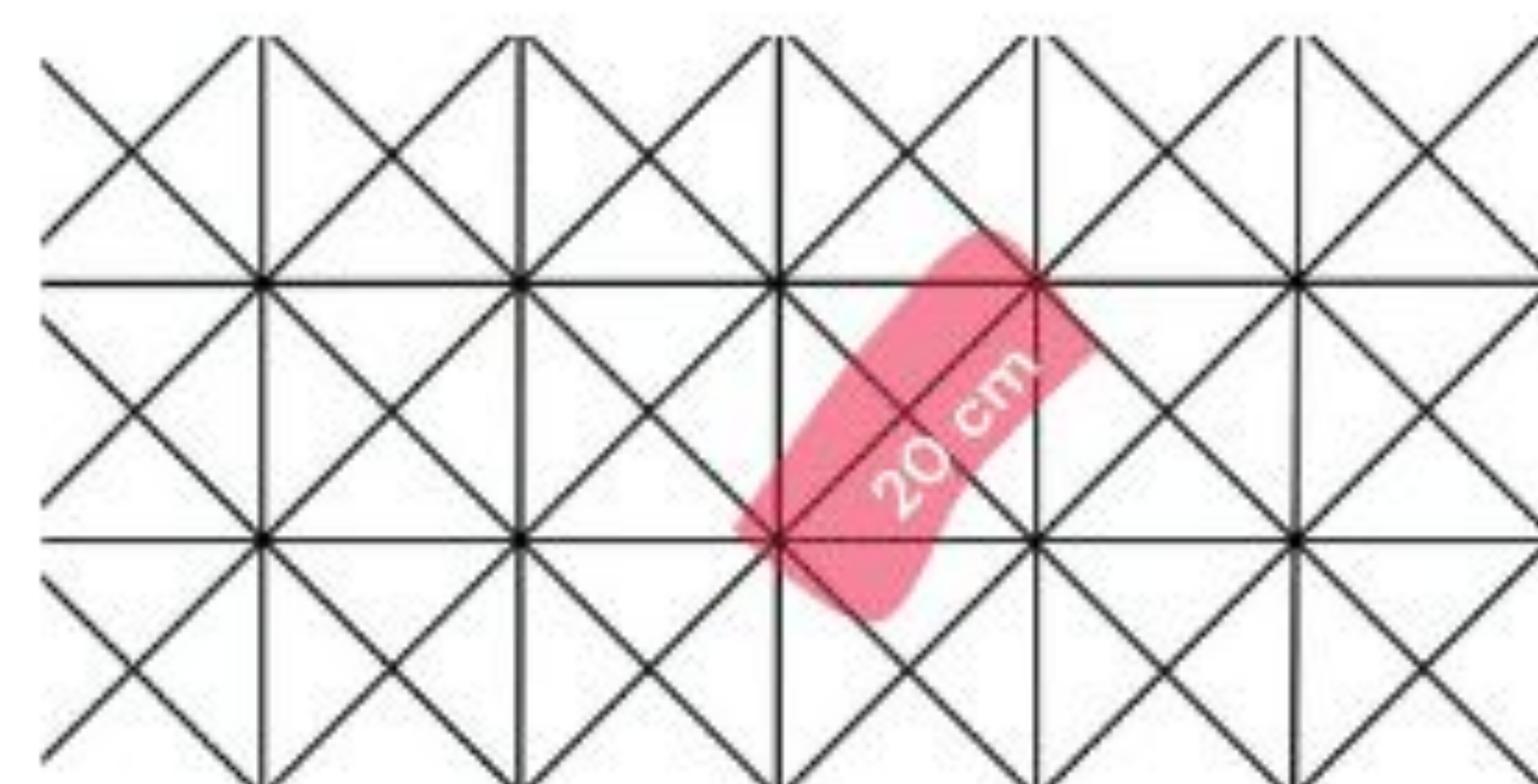
## Introduction

Math education and reform has been providing new ways of teaching mathematics to young students. In GRiD, geometry is taught to students using dance. In this study, we will be focusing on how students justify math concepts using verbal communication and non-verbal such as gestures and drawings.

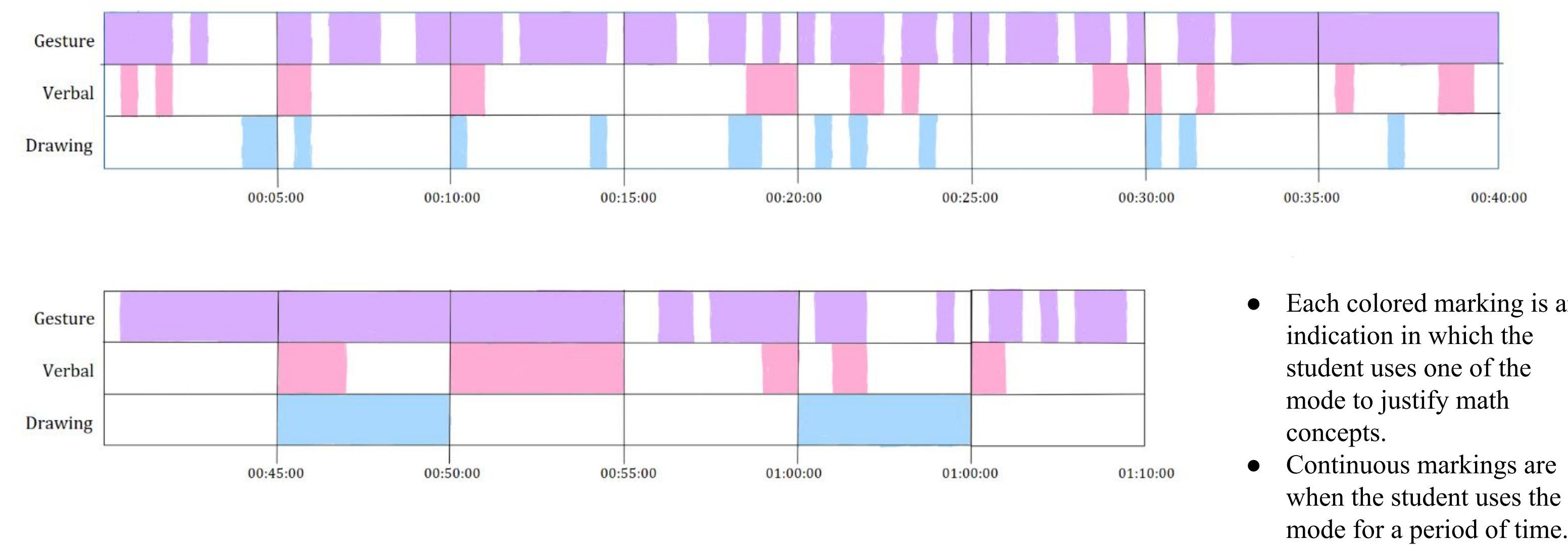
- **Gestures** are movements of the hands and body that uses dance to communicate mathematical understandings.
- **Drawings** are when the student uses a tool to create images on the GRiD to explain mathematical concepts.
- **Verbal communication** is when the student verbally explains mathematical concepts using dance terms and lessons.

## Methods

- The pilot video focuses on a student named Anna as she uses GRiD and Balinese dance as tools to understand angles. The video provides an insight into the student-teacher relationship as well as student cognition within embodied mathematics tasks.
- The main problem of this study relies on an essential component of Balinese dance, a 90° foot stance, which is converted into a geometry problem that prompts students to justify how they know their stance is at the correct angle.
- The study focuses on three primary conceptualization mechanisms which are utilized by the student to further her justification: gestures, drawing, and oral communication.



## Results



### Verbal

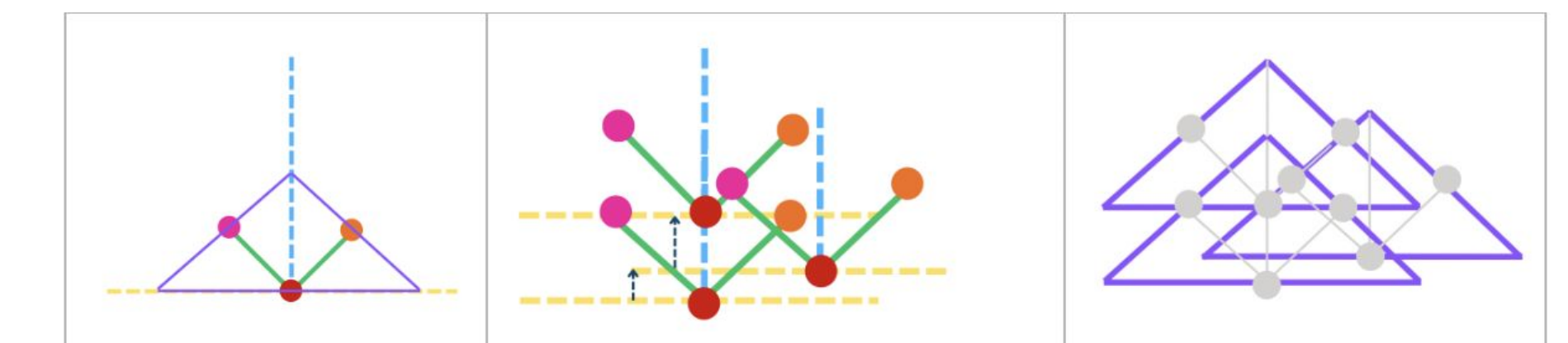
00:10:25	<p>A: when I go like this [right foot steps ahead, navy blue line traces the direction], I always tend to put my foot like over</p> <p>R: ehem</p> <p>A: like this [left foot steps ahead, navy blue line traces the direction],</p> <p>R: ehem</p> <p>A: But then I keep imagining myself to have another horizontal line here [blue line traces the gesture direction] another vertical line here [yellow line traces the gesture direction].</p> <p>A: So I feel like, um this ... [step back]</p> <p>R: ehem</p> <p>A: [bends forward] triangle-ish thing [purple lines trace gesture area] always stays with my feet, like whenever I move around.</p>	<p>A uses language such as “horizontal line” and “triangle-ish” along with gestures and drawings to justify the lines A sees. A also verbally explains the way they place their feet or where their feet goes during dancing. Combining the explanation of their feet positions in dance and math terms of lines, A utilizes verbal communication and Balinese dance to justify their feet being at a right angle.</p>
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### Gestural

00:10:06		Anna visualizes and points to and traces the horizontal line she associated with the positioning of her feet, saying that it remains in the same position relative to her when she moves forward.
00:10:08		Anna visualizes and points to and traces the vertical line she associated with the positioning of her feet, saying that it remains in the same position relative to her when she moves forward.
00:10:12		Anna sweeps both hands over the area in front of her, indicating a “triangle” that always stays with her feet when she positions herself at a 90° foot stance.

## Drawing

00:10:25	<p>A: [draws big triangle in front of where her original foot position was located]</p> <p>A: “this big like thing”</p> <p>R: “Ohhh”</p> <p>A: “cause I feel like this big one has all the horizontal and my two”</p> <p>R: “diagonals”</p> <p>A: “yeah diagonals”</p> <p>A: [traces her lines again while stating the lines in the triangle]</p> <p>R: “oh so you always have your triangle”</p>	<p>Uses the triangle as an attentional anchor. A uses this triangle to help guide her movements.</p> <p>If the triangle is in front of her then she knows her position continues to be correct.</p> <p>Recognizes that all her lines have to remain as she moves, and the triangle asserts that point for her.</p>
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## Conclusion

### Verbal Dialogue: Describing the Graph

- Verbal communication utilized many math terms and dance terms which was accompanied many times by gestures or drawings. Verbal justification tended to support the gestures and drawings being made to further explain the student’s thought process.

### Gestures: Embodying the Graph

- Gestures are the most commonly utilized modality within justification in diverse contexts, including for clarity and emphasis, to visualize and model ideas, to look at concepts through new perspectives, and to provide evidence.

### Drawing: Representing the Graph

- Through the action of drawing geometric figures, the student enhances their geometric intuition and spatial reasoning through the use of the GRiD. The visualization of shapes and lines helps the student in further constructing logical arguments.

### Multimodality in Mathematical Reasoning

- New questions introduced within the task were first and more typically explored gesturally and verbally, and then, if needed, further supported through drawings.
- The GRiD mat as a reference point, rather than typical pen and paper, opened novel opportunities to use broad and diverse gestures within explanations.

## Literature

- Abrahamson, D., & Shulman, A. (2019). Co-constructing movement in mathematics and dance: An interdisciplinary pedagogical dialogue on subjectivity and awareness. *Feldenkrais Research Journal*, 6, 1-24. <https://feldenkraisresearchjournal.org/index.php/journal/article/view/13/8>
- Gerofsky, S. (2011). Seeing the graph vs. Being the graph. In *Integrating gestures* (pp. 245-256). John Benjamins.
- Rosenbaum, L. F., Kaur, J., & Abrahamson, D. (2020). Shaping perception: Designing for participatory facilitation of collaborative geometry. *Digital Experiences in Mathematics Education*, 6(2), 191-212. <https://doi.org/10.1007/s40751-020-00068-2>