Gesturing Partition and Fraction Understanding: A Case of Primary Students Solving Partition Tasks

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This paper aims to understand how primary students use gestures to solve partition tasks and to what extent these gestures may promote fraction understanding. Analysis of six selected students' answers to partitioning tasks, classroom observation, and post-lesson interviews indicates that co-thought representational gestures play a critical role. The gestures help the students represent partitions that may not be readily available mentally. Gesturing partitions might allow students to extend their understanding of fractions.

Learning fractions has been challenging for students (Wijaya, 2017), while the topic is considered a gatekeeper's doorman in mathematics (Booth & Newton, 2012). The challenge appears to be rooted in multiple factors, such as the different meanings of fractions, the complex processes required to understand fractions, or instructional delivery. Partition is argued to be one of the underlying processes or concepts for fraction understanding (Lamon, 2020). In addition to partitioning, other underpinning concepts for fraction understanding are disembedding, iterating, splitting, and unit coordination (Steffe & Olive, 2010). Students who have interiorised the concepts are argued to be able to treat any fractions as numbers (Hackenberg, 2007). Many types of interventions have been implemented to address fraction learning (Roesslein & Codding, 2019), including the use of gestures (Beilstein, 2019). The term gesture is consistently used throughout this paper to refer to hand gestures. For example, Zurina and Williams (2011) found that gesturing for oneself helps students visualise fraction concepts. Despite the positive impact of gestures, literature indicates that only a few studies have focused on gestures in fraction content (Martinez-Lincoln et al., 2018). Moreover, considering the importance of the underpinning concepts, such as partition for fraction knowledge, very little is known about how the use of gestures, either by teachers or students, could help comprehend the concept, which might lead to fraction understanding. Therefore, this paper aims to address this gap by investigating students' use of gestures in solving partition tasks and to what extent gestures on partition might promote students' fraction understanding.

Partition, Gesture, and Fraction Understanding

In general, partition could be perceived as dividing an object or collection of objects into some disjoint parts. Regarding fractions, partition is to divide fractional objects or representations, for example, a fraction bar into equal parts or sizes. The equal parts of the object denote the existence of fractions (Lamon, 2020). The term partition is used in this paper, which means equipartitioning. For instance, Martin and Hunt (2022) provided students with partition activities, such as sharing one whole chocolate among an increasing number of children, as a foundational step prior to learning other fraction concepts, including iteration and unit coordination. The activities improved students' performance on the fraction test. It appears that teaching interventions involving partitions are frequently associated with students solving fair-sharing problems. In addition to the fair-sharing context, hands-on activities such as paper folding are promising for constructing the idea of partition (Empson & Turner, 2006).

Gesture is generally perceived as body movements. It represents actions (Novack & Goldin-Meadow, 2017) and frequently involves hands with speech (McNeill, 1992) or without speech (Logan et al., 2014). Speech-accompanied gesture is spontaneous hand movements that co-occur with speech (McNeill, 1992). Meanwhile, co-thought gesture is hand movements that

(2025). In S. M. Patahuddin, L. Gaunt, D. Harris & K. Tripet (Eds.), *Unlocking minds in mathematics education. Proceedings of the 47th annual conference of the Mathematics Education Research Group of Australasia* (pp. 453–460). Canberra: MERGA.

come along with students' thinking, for example, when processing task information (Logan et al., 2014). Three frameworks have been prominent in explaining gesture production and its function: gestures as representational action (Novack & Goldin-Meadow, 2017), gesture as simulated action (Hostetter & Alibali, 2008), and gesture for conceptualisation (Kita et al., 2017). As a representation action (GRA), gesture represents ideas, objects, or actions. As a simulated action (GSA), gesture emerges from spatial representations and mental images. Lastly, for conceptualisation (GfC), gesture could activate, manipulate, package, and explore spatio-motoric information for speaking and thinking.

In their review of journal articles on gesture research targeting teachers/students from preschool to grade 12 in mathematics classrooms, Martinez-Lincoln et al. (2018) suggest that the use of gestures either by the teachers or students in mathematics teaching and learning improves students' mathematical achievement. Of the inclusion studies, only one study focused on fractions (Zurina & Williams, 2011), investigating how primary students conceptualised fractions through gesturing the number of equal-shared bread pieces for oneself. After the review, there appear to be a few gesture-fraction studies. For example, Beilstein (2019) found that a student used gestures to make partitions and iterations on number lines, which could be a resource to develop students' number-line skills. The study then implemented a gesture-based fraction intervention where the teacher demonstrated a hand gesture to partition the number lines (partitioning gesture). Some other studies also embedded gestures in fraction interventions, for example, using chunking gestures to represent the magnitude of unit fractions on number lines (Barbieri et al., 2020). Given that partitioning is foundational to fractions (Lamon, 2020), the studies indicate that the use of gestures by the teachers could help students visualise the concept/process, or by the students to represent the concept/process, which might be unavailable mentally.

To sum up, partition is a concept that underpins fraction understanding (Lamon, 2022). Thus, facilitating learning that helps students interiorise partition is critical. Gestures help students improve mathematics performance (Martinez-Lincoln et al., 2018), including fractions. However, in general, the gesture-fraction relationship is under-researched (Beilstein, 2019). Specifically, concerning Beilstein's study, little is known about how gestures could help students represent/process partition and promote fraction understanding. Therefore, this paper focuses on these questions: (1) How do students use gestures to solve partitioning tasks? and (2) To what extent does the use of gestures on partition promote students' fraction understanding? The answers to the questions could likely lead to our understanding of how gesturing partition could promote fraction understanding and how gestures could be a pivotal part of teaching intervention that helps students learn and understand fractions.

Methods

Research Context and Participants

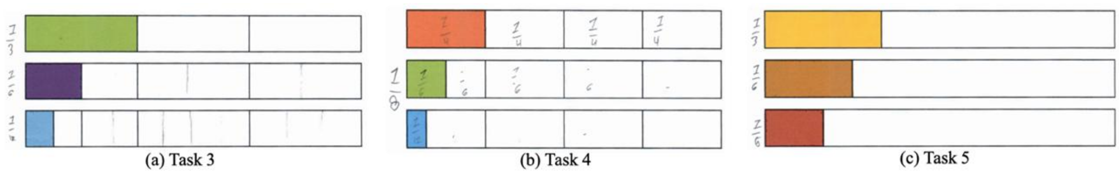
This paper is part of a larger intervention study that aims to help students develop the underpinning fraction concepts (Steffe & Olive, 2010), including partition through a classroom intervention that had spatial reasoning as its core foundation. The intervention comprised eleven lessons, two of which were devoted to partition and are reported in this paper. Thirty-one grade 4 students participated in the intervention delivered by their classroom teacher as part of a regular classroom schedule. Six students (2 males, 4 females) were purposively selected based on the result of a fraction scheme pre-test (Norton & Wilkins, 2009), in which they demonstrated a mix of abilities. To solve the fraction scheme test, students need to have developed the underpinning fractions concepts: partition, disembedding, iteration, splitting, and unit coordination. The selected students were continuously observed during the intervention and interviewed after the pre-test, lessons, and post-test. All names reported in this paper are pseudonyms.

Partitioning Activities and Tasks

In general, the intervention engaged students with physical and then mental spatial activities, which aim to help students move from concrete to abstract experiences. In the physical partitioning activity, students in small groups folded paper strips equally, which introduces the idea of equal partitions. Prior to the group activity, the teacher demonstrated paper folding using the paper strips and then used hand gestures accompanied by speech to show the process of folding the paper strips (folding gestures) and the result of the paper folding (partitioning gestures). In the mental partition activity, five individual tasks were given. In Tasks 1-2, students were given four fraction bars; three were blank, and one was partially partitioned. The tasks expect students to make different partitions and reason about the relationship between the different numbers of partitions. For Tasks 3-5, given full and partial partitioned fraction bars where some parts were coloured (Figure 1a: 3/3-bar, 6/6-bar, 12/12-bar; Figure 1b: 4/4-bar, 8/8-bar, 16/16-bar; Figure 1c: 3/3-bar, 4/4-bar, 6/6-bar) and the bars are not equal in length, students were expected to identify fractions that represent the partitioned part(s). The mental partition activity was enacted through a VPC (visualise, predict, check) teaching heuristic (Patahuddin et al., 2020). At the visualise stage, the teacher helped students visualise partition by re-demonstrating the paper folding and demonstrating selected tasks using co-speech representational gestures. Afterwards, the students predicted the answers to the partition tasks individually, where they were allowed to use gestures only, no other aids such as fraction strips. At the check stage, the students checked their predicted answers using paper strips.

Figure 1

Partitioning Tasks



Data Collection and Analysis

The sources of data for this paper are six students' answers to the partitioning tasks (a total of 30 answered items), videos and transcripts of students' semi-structured interviews after the partitioning lesson (12 transcripts), and classroom observations (two lesson videos in which their activities during the lessons were captured through video recordings and the researcher's field notes). The interviews focused on how students processed the tasks and what fraction understanding they had developed during the intervention. Sample questions asked were: How did you solve the task? How did you use your hands to solve the task? Why does the part show the fraction? The steps of the analytical model of videotape data analysis (Powell et al., 2003) were referred to for the analysis of interview and lesson videos: watching the videos attentively, identifying critical events, transcribing, coding, and constructing themes/categories of gesture use and fraction understanding. For example, the students' use of gestures for solving the tasks gives rise to three categories: gesture type, gesture purpose, and gesture-task relation. The type of gestures is co-thought representational gesture (Novack & Goldin-Meadow, 2017).

Results and Discussion

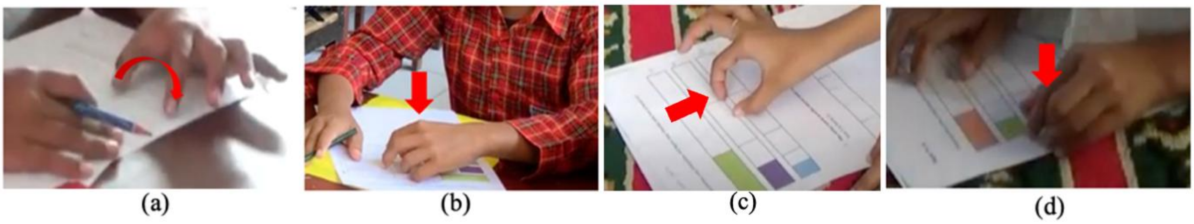
The results are organised into two parts pertaining to the research questions, in which evidence on students' use of gestures in solving the tasks and the students' fraction understanding that might be promoted by their ability to make partitions using gestures is presented.

Gestures on Partitioning

All the students gestured prior to making partitions on the fraction bars in Tasks 1-2. They placed their hands, forming a V-shape between their thumb and index fingers, and moved their hands on the bars (red curved arrow in Figure 2a). The V-shape is adjustable to the number of partitions made. The students argued that using their hands helped them make the partitions (T1 lines 1-4; T2 lines 1-2). When asked how they knew that each partition was equal, they also used gestures (for example, T2 lines 3-6). Furthermore, most students could make the inference that the more partitions on the bar, the smaller the parts.

Figure 2

Students Using Gestures for Solving the Tasks



Transcript 1 (T1) – R: Researcher, H: Hana

1 R: why was it easier to use hands [Task 1]?
2 H: it is just like this [placing her hands on the bar] then marking it.
3 R: what is the difference between just imagining the bar and marking it [directly making partitions] and using the hand first?
4 H: if not using hands some are bigger and the other are smaller […]
5 R: how did you solve it? [Task 3]
6 H: it is like this [pointing the partitioned line in the 6/6-bar, Figure 1a] so it was equal
7 R: did you use your hand?
8 H: yes like this [partitioning the bar into 6 equal parts using gestures, Figure 2c]

T2 – R: Researcher, L: Lili

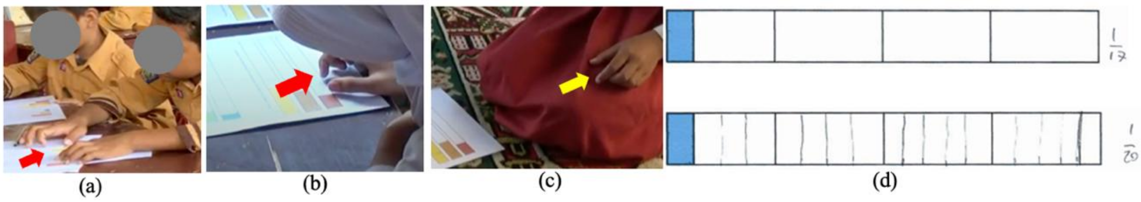
1 R: how did you solve it [Task 1]?
2 L: First I used my hands then used my hands again to find the answer in the third trial.
3 R: back to your answers how did you know that these [The partitioned parts of the 3/3-bar] were equal?
4 L: I used my hand
5 R: how?
6 L: [use gestures to show the equal size of the partitions] […]
7 R: how did you know that this coloured part is 1/6 [Task 3, 6/6-bar Figure 1a]?
8 L: The teacher said it must be equal so how did I get 1/6 I used my hand and then drew the lines.

Unlike Tasks 1-2, the students processed Task 3 differently. The tasks asked them to determine fractions representing the coloured partitioned parts (Figure 1a). This task is more challenging than the previous tasks, the students need to see the relationship between the coloured part and other parts within the bar. For the 3/3-bar (Figure 1a), all the students could directly determine 1/3 without gesturing. To determine fractions in the other two bars (Figure 1a, 6/6-bar, 12/12-bar), all students used gestures. Two students were observed to gesture when solving the task (Figure 2a-b). In the post-lesson interviews, for example, for the 6/6-bar, Lili gestured and then drew partitioned lines within the bar (T2 lines 7-8, Figure 1a). Similarly, Hana gestured for determining 1/6 (T1 lines 5-8) and 1/12 for the coloured parts in the two bars. One student (Zane) directly knew the answers, did not make any drawings or partitions on the bars, and gestured to confirm her answers. She argued in the interview that she identified connections between bars she partitioned in Task 1 and bars in Task 3. The three bars in Task 1 were partitioned into 3, 6, and 12, respectively.

Students were allowed to gesture when solving Tasks 1-3. Meanwhile, for Tasks 4-5, the students were asked to predict the answers to the tasks without gesturing. This could reveal whether the students could determine fractions without gestures. Zane was absent from the lesson. For Task 4 (Figure 1b), all five students could determine 1/4 for the 4/4-bar. However, without the presence of gestures, only two students could determine correct fractions for the remaining two bars (8/8-bar, 16/16-bar). The other three students answered 1/17, 1/10, and 1/12 for the 16/16-bar, and some of them had 1/6 for the 8/8-bar. Similarly, only one student had correct fractions for all the bars in Task 5 (Figure 1c), two students had 1/8 and 1/9 for the 6/6-bar, one student had 1/6 for the 4/4-bar, and another student had no answers. When they were asked to check their answers during the lesson and allowed to use gestures, the student who had no answers for Task 5 was observed to gesture and determine correct fractions for the bars (Figure 3a). Another student, Lili, answered 1/9 for the 6/6-bar in Task 5. After using gesture (Figure 3b), she found the bar to be six equal parts and revised her answer to 1/6. Moreover, the other student, whose initial answer was 1/17 for the 16/16-bar in Task 4, checked his answer using his hand and got 1/20 (Figure 3d). He was able to partition the bar but made six partitions within each of the last two bigger parts. Some other students reworked their incorrect answers in the after-lesson interviews using gestures. For example, as shown in Figure 2d, Anna rechecked the answer on the 8/8-bar by gesturing to come to the revised answer, 1/8 (Figure 1b). She was asked to rework the 4/4-bar where her initial answer was 1/6 (T3 lines 1-6).

Figure 3

Students Checking/Reworking Tasks Using Gestures



T3 - R: Researcher, A: Anna

1 R: is this 1/6? [pointing to the 4/4-bar, Figure 1c]

2 A: yes

3 R: could you imagine it again? [could you rework it by mentally processing the task]

4 A: [while reworking the bar, her hand silently forms a V-shape gesture, Figure 3c) it is 1/6?

5 R: you can try using hands.

6 A: [partitioning the 4/4-bar using hand gesture] it is four

Based on the students' answers to the tasks and post-lesson interviews, there are three emerging categories regarding the students' gestures on the partition tasks: gesture type, gesture purpose, and gesture-task relation. First, the gestures used by the students, the thumb and index finger forming a V-shape, represent an action (making equal partitions) and were performed silently, called co-thought representational gestures, which might play self-oriented cognitive functions (Kita et al., 2017; Logan et al., 2014). For example, before drawing partitioned lines in Task 1-2, all the students gestured to determine equal parts (T1 lines 1-4). Another example is how Anna attempted to rework the 4/4-bar in Task 5 by self-directing her thinking through gestures (Figure 3c). Other studies also reported such a function of gestures. For example, Zurina and Williams (2011) documented how a student gestured for oneself to conceptualise fractions through the number of shared beard pieces. In addition to this study, the result of the present study provides another insight into the students' use of co-thought gestures for partition, which is considered the foundation for fraction understanding (Lamon, 2020). Second, at the individual level, the gestures could be seen as a primary and supplementary action. When solving Task 3, the students appeared to use the gestures differently, where most of them used gestures to directly make the partitions (primary gesture), and one student gestured after solving the task to confirm her answers (complementary gesture). This aspect of the use of gesture is still questionable since the student with complementary gesture did not answer Tasks 4-5 due to her absence during the lesson. More data is required to understand how this aspect of gesture purpose is at play.

Third, at the task level, gestures are not always used by the students to solve the tasks. First, all the students gestured for making partitions in Tasks 1-2 and determining fractions within partially partitioned bars in Task 3. Second, all the students could directly determine fractions without gestures for the 3/3-bar in Task 3 and the 4/4-bar in Task 4, which are fully partitioned. Third, for partially partitioned bars in Tasks 4-5, some students used gestures while others did not. The gesture theories (Hostetter & Alibali, 2008; Kita et al., 2017) might provide explanations for the phenomenon. Hostetter and Alibali (2008) proposed three factors contributing to gestures, two of which are the strength of simulated action and the gesture threshold. For the students who did not need gestures, the tasks might not have sufficient difficulty or power to simulate their gestures. Moreover, their gesture threshold or the level of gesture activation is high due to the low cognitive load from the tasks. This is possible since the bars are fully partitioned; they could directly 'see' the partitions within bars. In other words, the more demanding the task, the more gestures are required. This could be relevant to fraction bars that are not fully partitioned, where they first need gestures for making partitions and then determine fractions. Research also points out this phenomenon on map tasks (Logan et al., 2014). Cognitive load as one of the determinants for the gesture threshold, appears to associate with the role of gesture for conceptualisation (Kita et al., 2017), which is to maintain spatio-motoric information. The students' difficulty in maintaining the information from the tasks could have triggered more gestures. For the case of Tasks 4-5, where some students could determine correct fractions without gestures, two potential reasons are the individual's difference in gesture threshold, or the students had been familiar with the tasks. Despite these possible explanations, further investigations are required to understand this phenomenon.

To conclude, the gestures help students directly/physically act on the fraction bars, rather than spatially/mentally process the partitions, which might not yet be available to them. The case of Anna (Figure 3c, T3 lines 1-6) depicts this, for example. These gesture-made partitions might allow the students to see the relationship between the partitioned parts within the bars, for example, in Tasks 1-2, where they could argue that the more partitions, the smaller the parts. This is likely to enable the students to determine fractions representing the partitioned parts. This finding could extend our understanding of how primary students use co-thought representational gestures in solving tasks involving partitioning, which is one of the concepts that underpins fraction understanding. Additionally, it contributes to gesture-fraction literature, which seems to mostly cover how teachers gestured (e.g., Barbieri et al., 2020; Beilstein, 2019) or students/participants used co-speech gestures to communicate fraction ideas (Edwards, 2009).

Gesture, Partition, and Fraction Understanding

Literature suggests that apprehension of partition, including the relationship between the partitioned parts within fraction representations, is the underpinning process for fraction understanding (Lamon, 2020). In the post-partition lesson interviews, in addition to how the students solved the tasks, they were also asked about their understanding of the process. The coding of the data resulted in five categories of fraction understanding. Due to the page limit, selected interview transcripts supporting the categories are presented. First, all the students were aware that the equally partitioned parts represent fractions and could explain why. Second, only one student (Lili) could not argue that each partitioned part represents the same fraction and needs to fold back to the folded fraction strips to have that understanding. Third, after folding back, the student and the other four students could identify that the total number of partitioned parts determines the fraction (T4 lines 1-4). Lili had not developed the next two categories of understanding. Fourth, the other five students could observe that the smaller the partitioned part, the smaller the fraction (T4 lines 5-10). Lastly, the students were able to identify the whole (n/n) as the result of summing up all the parts (T4 lines 11-14).

T4 - R: Researcher, A: Anna, L: Lili, Rn: Rian

1 R: why 1/6?

2 L: because it is partitioned into 6 parts

3 R: why this and this have different fractions? [pointing to the coloured part of the 6/6-bar and 3/3-bar in Task 3]

4 L: because they have different parts […]

5 R: can you order the coloured parts from the longest? [Task 3]

6 A: 1/3 1/6 1/12

7 R: is the fraction representing the shortest part the smallest?

8 A: [nods her head]

9 R: why?

10 A: because the part is getting shorter […]

11 R: what do you find if they are added? [prior to this, he could identify two parts of the 6/6-bar are 2/6]

12 Rn: the whole

13 R: what fraction is the whole?

14 Rn: 6/6

It appears that the students were reliant on gestures to make partitions when solving some of the tasks. For example, some students could not directly determine fractions in the absence of gestures in Tasks 4-5 and then reused gestures in the lesson and interviews to rework the tasks (Figure 3, T3). Further interviews show that five of the six students have a solid understanding of fractions, not only arguing, for example, why the fractions represent the coloured parts but also reasoning on fraction comparisons. This might indicate the impact of gestures on fraction understanding through gesturing partitions. The students' gestures representing the action of partitioning in the present study possibly helped them build a mental model of the role of equal partition, allowing them to understand relations between the partitioned part(s) that produce fractions. For example, the smaller the partition, the smaller the fraction (T4 lines 5-10); the presence of the hands might facilitate this understanding, enabling students to directly see or visualise the partitioned part(s) that represent the magnitude of the fractions. Presmeg (2006) asserts that gestures help students visualise.

Implication and Limitation

This paper contributes to our understanding of how students use gestures for partitioning, which is one of the underpinning fraction concepts, and to what extent the partitioning gesture could possibly promote fraction understanding. The findings further emphasise the role of gestures in fraction teaching and learning, as other studies have documented (Beilstein, 2019). Moreover, the teaching intervention in the present study shed light on how gestures could be purposively and explicitly enacted in the classroom and involve partition; the teacher demonstrated co-speech representational gesture, with other resources, such as fraction manipulatives and representations. Thus, one of the potential approaches to address the challenge of learning fractions in primary schools is for the teachers to model gestures and for students to be prompted to use gestures alongside representations. The data in this paper is from a small number of students, indicating the limitation of the findings.

Acknowledgements

I thank Tracy Logan and Sitti Patahuddin for providing feedback on this paper and the Australia Awards Scholarship for funding the PhD study. Ethics approval (13513) was granted by the University of Canberra.

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