Interpreting and Using Gestures of English Language Learners in Mathematics Teaching

Anthony Fernandes and Laura McLeman

Abstract

This article describes, through two vignettes, the use of gestures in the context of mathematical task-based interviews with 6th-grade students who are English language learners (ELLs). The first vignette illustrates the students' gestures associated with the concept of area and perimeter and the second vignette displays the effective use of gestures in supporting the students' thinking. Implications for teaching are also discussed.

Discussion And Reflection Enhancement (DARE) Pre-Reading Questions:

1. How are gestures connected to speech?
2. List some of the gestures you have seen ELLs make as they communicate their mathematical thinking. How have you used these gestures to interpret and build upon their mathematical thinking?

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Spontaneous hand movements that usually occur when people speak are a very common type of gesture (McNeill, 1992). The goal of this article is to examine how such gestures can prove useful when teaching mathematics to English Language Learners (ELLs). In particular, we outline how gestures can play a role in (1) interpreting ELLs' thinking and (2) guiding ELLs' mathematical work. Each point will be illustrated through a vignette that occurred in the context of task-based interviews with ELLs at two locations in the United States.

One theory about gestures considers them an add-on to speech that provides no information beyond that conveyed in the associated speech (Hadar & Butterworth, 1997). Another theory posits that gestures and speech form an integrated system that provides more insight into a person's thinking (Goldin-Meadow, 2005; McNeill, 1992). This latter theory is bolstered by theories of embodied cognition which assume that knowledge is constructed through bodily experiences in the environment (Lakoff & Núñez, 2000; Radford, 2003, 2009; Wilson, 2002). As such thinking, learning and teaching are multimodal processes that involve speech, words, signs, gestures, artifacts, and visual representations (Arazello, Paola, Robutti, & Sabena, 2009). This paper highlights the gesture mode in interactions with ELLs.

Gestures rely on visual imagery and convey meaning globally, unlike speech which relies on linear segmentation and conveys meaning discretely. For example, moving the forefinger in a circle can describe at once the spatial arrangement of people sitting in a circle, as opposed to the sentence "The people were sitting in a circle". Further, if the gesture and speech co-occur, the information encoded in the gesture is not necessarily redundant as it can also indicate to the listener the location of the seating arrangement in the room. The different information conveyed in the speech and gesture modes can prove to be valuable in educational contexts. For example, Perry, Church, and Goldin-Meadow (1988) found that when some 10-year-old children were asked to solve missing value problems like 3 + 4 + 5 = _ + 5, their strategies in speech and gesture differed. In their speech, the students conveyed a strategy that involved adding the numbers on the left to get 12, which they put in the blank (an incorrect solution). However, the students simultaneously pointed to the numbers 3 and 4, which -- if added -- would give the correct solution of 7. The gestures and speech of these students differed from another group of students who pointed to 3, 4, and 5 in succession as they put 12 in the blank. The researchers observed that, after receiving instruction, the former group performed better on similar items on the post-test.

Gestures are especially useful in communication when the speech may not be understood by the listener (Gullberg, 1998; Church, Ayman-Nolley, & Mahootian, 2004). Using gestures with students who are beginning to learn English can be very fruitful. For example, Church et al. used a pre-test to divide 51 first-graders consisting of 26 native English speakers and 25 native Spanish speakers into two groups, with each group including half of the students from each language category. One group was then provided instruction on conservation tasks involving volume and quantity (e.g., pouring water from one container to another with a different shape preserving the amount of water even though the water levels varied) using speech (first in English and then in Spanish) and gestures, while the other group was provided the same instruction in speech only. Both groups were later tested on conservation tasks. Questions were posed verbally in testing videos, both in English and Spanish, and the students were required to circle on an answer sheet if the quantity was conserved or not (S- Same, D-Different or M-Mismo, D-Diferente). Findings indicated that both language populations in the group that was exposed to gestures and speech scored higher on the post-test. Shein (2012) describes the use of a 5th-grade mathematics teacher's gestures to support her discourse practices of questioning and re-voicing as she engaged her students, all of whom were ELLs, in mathematical discussions to correct errors they made in finding the areas of geometric shapes. For example, the teacher built on the students' gestures to clarify the meaning of height by gesturing vertically and diagonally. Thus, through the gestures she intuitively conveyed the idea of the height being perpendicular to the base – something that may have been more challenging just to convey in words for her students. Neu (1990) also found that ELLs could "stretch" their linguistic competence through the use of gestures. In the case of ELLs who are still in the process of learning academic language, gestures can assume a larger significance in interpreting their thinking and helping them learn. Moschkovich (1999, 2002) asserted that bilingual students' mathematics work is best interpreted within a situated-sociocultural perspective where resources like gestures, along with objects and the use of native language, are integral to making meaning in mathematical communication.

Context

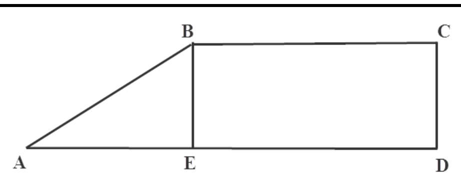
The two vignettes were chosen from a corpus of task-based interviews that were conducted in two phases with ELLs in grades 4-8 in the Southwest or Southeast regions of the United States. Phase one aimed to understand the linguistic challenges ELLs faced as they communicated their thinking and the resources that they used in the process. In phase two, the first author sought to extend this method to prepare PSTs to work with ELLs by understanding the involved challenges and resources.

Three researchers (including the first author) conducted the first phase, which yielded a vignette involving a 6^{th}-grade Spanish-speaking student from a school that was located in a working class neighborhood in the southwestern United States. The second vignette, selected from the second phase of the project, involved 32 preservice teachers (PSTs) from the first author's geometry class interviewing ELLs at a local school. This vignette involved a 6^{th}-grade Spanish-speaking student who attended a school in an urban city in the southeast United States with a rapidly growing Latina/o population.

Four National Assessment of Educational Progress (NAEP) measurement tasks that varied in difficulty (as judged by NAEP) and grade level were selected from a larger collection of NAEP measurement problems. Note that the NAEP is conducted only with students at the 4^{th}, 8^{th} and 12^{th} grade levels, thus the tasks for 6^{th}-graders were a blend of tasks from the 4^{th} and 8^{th} grade assessments. The tasks were tested in initial rounds of phase one and were selected because they involved linguistic facets that challenged ELLs, but at the same time garnered creative responses that included informal thinking, drawings, and concrete materials to solve the task. In both phases, the student was first asked to solve the problems independently and then explain his/her thinking process. Further probing questions were always asked to uncover the student's thinking process. The interviews were usually conducted by two persons, one interviewing and the other videotaping.

Vignette 1: Area and perimeter gestures

This vignette[1] focuses on Rita, a 6^{th}-grade Latina student who was interviewed in English by a university researcher named Carol. Rita was working on the Trapezoid Problem in Figure 1. In particular, we discuss Rita's use of gestures as she discussed the concepts of area and perimeter.



The area of rectangle *BCDE* shown above is 60 square inches. If the length of *AE* is 10 inches and the length of *ED* is 15 inches, what is the area of trapezoid *ABCD*, in square inches? (NAEP 1992, 8^{th} Grade, question #6 from Block M12; http://nces.ed.gov/nationsreportcard/itmrlsx/search.aspx?subject=mathematics)

Figure 1. The trapezoid problem.

After reading the problem, Rita mentions that she is unable to understand the problem and Carol proceeds to uncover what she knows, with the intention of assisting her to solve the problem. The interaction below involves Carol trying to get Rita to interpret the information given in the problem and write the measurements in the figure at appropriate places. Rita's gestures are particularly interesting to note when she is asked to put the "60" in the figure.

C: Okay, so… what they are talking about?

R: [*After a slight pause*] That all of this [*points to the base with the pencil* (see Figure 2)] this [*changes the pointing to BCDE* (see Figure 3)] rectangle is 60.

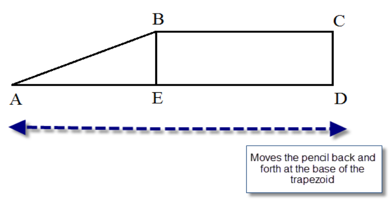


Figure 2. Rita's movement along the base of the trapezoid.

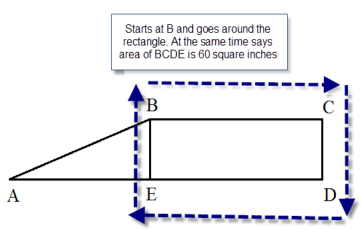


Figure 3. Rita traces along the outside of the rectangle.

C: Okay, so can you put the 60 somewhere in the figure and to keep in mind this information?
R: Right here [*points to BC with the pencil* (*see Fig. 4*)]
R: [*Writes 60 inside the rectangle just below BC*]

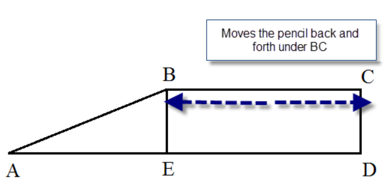


Figure 4. Rita traces along the length of the rectangle.

The gestures that Rita uses are linear in all instances. She initially points to the base of the trapezoid while verbalizing area of rectangle *BCDE* and then changes her gesture to outline the rectangle *BCDE* in the figure. What is noteworthy is that both gestures indicate a linear measurement, not a display of space, as given in the problem [see Figure 1]. Again, when asked to write the 60, Rita points to *BC* and writes 60 below it, as one would indicate a line segment's length.

Further into the interaction, Carol tries to scaffold the Trapezoid problem by asking Rita to draw a separate rectangle with lengths of her choice and work out the area. Rita mentions that the lengths of the sides of the rectangle should be added to get the area. Carol draws Rita's attention to a previous problem where she had added the sides to get the perimeter, implying that perimeter and area could not be calculated in the same way. Referring to the rectangle that was drawn, Carol probes Rita about perimeter and area.

C: If you were to explain to a 4th-grader what perimeter is, how would you explain it?

R: The inside of any shape [*simultaneously outlines a square or rectangle* (Figure 5) *on the table with the eraser that was on the pencil she had in her hand*]

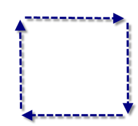


Figure 5. Rita's movement while explaining the concept of perimeter.

…
[*8-second pause*]
C: What is area?
R: Oh the inside [*simultaneously outlines a square or rectangle* (Figure 5) *on the table with the pencil eraser*] and the perimeter is the outside [*shifts hand from the table to the paper and moves the pencil eraser around the outside of the square provided in a previous problem that she solved correctly (Fig. 6)*]

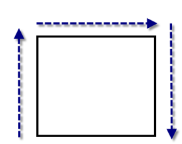


Figure 6. Rita's movement while explaining the concept of area.

Rita uses the same gestures to refer to the area and the perimeter of the rectangle. When referring to area, she said 'inside' but outlines line segments to indicate a square or rectangle. When discussing perimeter, Rita goes back to the figure of the square that was provided in the previous problem and outlines line segments, though these are now literally on the outside of the square. Rita probably interpreted the 'inside of the shape' (when referring to area) to mean just inside the boundary of the object, but still measuring length instead of space and the 'outside of the shape' (when referring to perimeter) to mean measuring lengths outside the boundary of the shape. At no point did her gestures for area seem to indicate the enclosed space in an object. When probed by Carol, Rita's use of similar gestures could account for the same calculations (adding up the sides) she was doing to work out the perimeter and area of the rectangle.

Vignette 2: Gestures supporting instruction

In this vignette, Tess and Matt, both preservice teachers, interviewed[2] Carla, a 6th-grade ELL on the Tile Problem (Fig. 7). Carla was provided a 0.5-inch graph sheet, and she worked on the problem independently for 12 minutes before she indicated that she was ready to discuss her thinking.

The Tile Problem

How many square tiles, 5 inches on a side, does it take to cover a rectangular area that is 50 inches wide and 100 inches long?

(NAEP 2009, 8th Grade, question #17 from block M5; http://nces.ed.gov/nationsreportcard/itmrlsx/search.aspx?subject=mathematics)

Figure 7. The interview task given to Carla.

Tess, who was the interviewer, asked Carla to explain her solution. Carla used a lot of pointing gestures to explain that she counted the squares along the length (39) and width (30) of the graph sheet, oriented in landscape view in front of her, and multiplied these numbers to get a total of 1170 tiles (Note that Fig. 8 shows a cropped graph sheet with the entire width, but only part of the length). Tess then asked Carla what information was provided in the "story problem".

T: And how many [tiles] did it tell you in the story problem?

C: [*Reading from the problem*] If 5 inches of side (sic) [*starts to move the pencil to point to the bottom of the graph sheet where she had counted 10 tiles and had written "5 inches on a sid[e]" (Fig. 8)*]. It says if 5 inches of side (sic) [*moves pencil in the air from the left end to the right end of the graph paper as she utters "side" and then retracts the pencil to the initial point (Fig. 8)*]

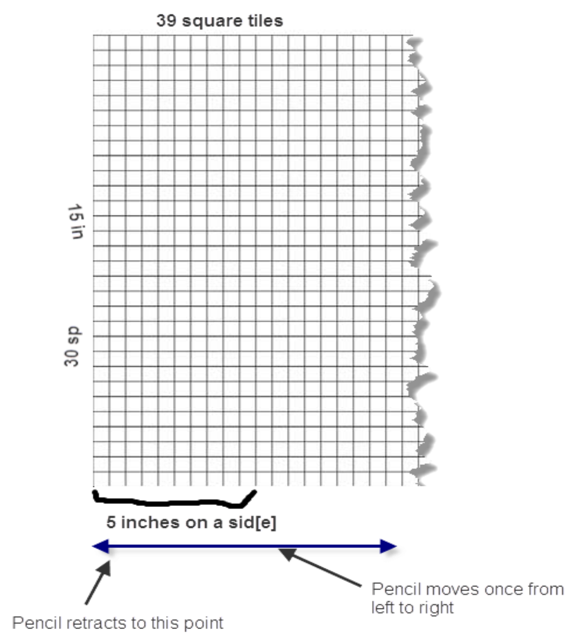


Figure 8. Reproduction of Carla's work (in boldface) on the graph paper.

Note that since this was a 0.5-inch graph sheet, the 10 squares that she marked would represent an actual measurement of five inches. Key to Carla's explanation of the tile measurement is her gesture as she utters "side" and moves her pencil, in the air, along the side of the graph sheet. She did not refer to the square on the graph sheet as a tile, even though she made this assumption for her initial solution. Her initial work shows that Carla has some idea how to solve the problem but she is unsure how to interpret the phrase "5 inches on a side," which she assumes is a linear measurement related to the side of the rectangle. The artifacts themselves do not create meaning; instead, they act as a background on which the student draws certain features to the attention of the listener. Thus, the gesture employed by Carla clarifies to Tess her meaning of "side" in the phrase "5 inches on a side".

In further interactions, Tess attempts to support Carla through mostly verbal instructions with a few pointing gestures. First, she instructed Carla to draw a rectangle of any size in order to represent the 100" by 50" rectangle given in the problem. Using this representation, Tess then asked Carla to "pretend that there are 5-inch tiles inside [of the rectangle]." When this strategy of imagination failed to help Carla progress in the problem, Tess instead asked Carla to think about how division might help her. Through these questions and different strategies, it seems that Tess was challenged to pinpoint exactly why Carla was struggling as well as how to help her proceed.

After observing Carla's interaction with Tess, Matt interjects and assumes the role of the interviewer. Matt uses concrete materials in conjunction with gestures to mediate the interactions with Carla. He uses a graph sheet to represent the 100" by 50" rectangle and a square cutout to represent the tile.

> M: Ok so can we just take this, so here is the graph paper [*takes the paper that is lying on the table*] and let's just pretend that this [*moves finger up and down along the longer side of the sheet oriented in portrait view*] is a 100 inches long and this is going to be 50 inches this way [*moves finger side to side along the shorter side of the sheet oriented in portrait view*]. So this is one of the shapes that you used in the other problem [*holding up the tile*]. So if that [*holds up the cutout*] was the tile that is 5 inches on each side, what would the measurement be on this side? [*points to one of the sides*]
> C: [*points with pencil in space*] five
> M: Five. How about his side? [*points to the next side*]
> C: Five
> M: This side? [*points to the next side as he rotates the cutout*]
> C: Five
> M: And this side? [*points to the last side as he rotates the cutout*]
> C: Five
> M: It's five on all sides, right? So could we go ahead and if this [*points to the length of the graph sheet*] was a hundred inches long, can we put this on here [*places tile in the bottom left corner of the sheet* (see Fig. 9)]. How many of these would it take [*starts moving the tile up the sheet and emphasizes this motion by tapping down on the table after each addition*] if it was a hundred inches. [*C starts doing some calculations on her paper*]
> C: Twenty!

Carla successfully works out the tiles that would fit along the width and the total number of tiles it would take to cover the entire rectangle.

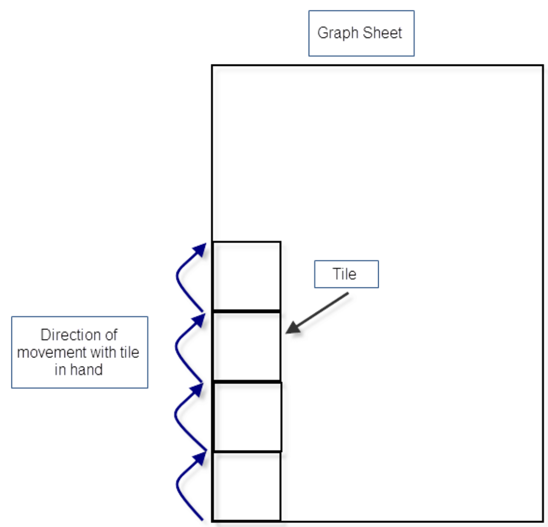


Figure 9. A representation of Matt's support for Carla.

In a written report[3], Matt explains the reasoning behind the guidance he provided. In particular, he shares how he focused his attention on a possible confusion that Carla may have had with the wording of the problem. Based on how Carla drew a line to represent the "5 inches on a side" (Fig. 8), he conjectured that the 5 inches referred to a measurement on "a side" of the larger rectangle rather than all four sides of the square tile. Matt also conjectured that this was because she may have encountered the dimensions written in the more familiar format of 'each side was 5 inches' or '5 by 5'. Matt first takes the graph sheet and makes salient the dimensions of 100 inches and 50 inches by pointing to the length and width respectively. By using the word "pretend", Matt attempts to distinguish this approach from Carla's first attempt where she worked out the area by multiplying the actual number of squares along the length and the width. He takes the cutout from a prior task and once again emphasizes the dimension of each side by pointing to it and asking Carla to confirm the measure. This move was key for Carla to understand the phrase "5 inches on a side" and both the cutout and the gestures play an important role in confirming, for Carla, the word "side" in the phrase. Finally, Matt's gesture of moving the cutout up the side of the sheet and simultaneously using a rhythmic tapping gesture adapts Carla's first method (where she counted squares along the length and width) and she is able to find the solution. Matt's speech — "How many of these would it take if it was 100 inches" — is not enough to convey the method he had in mind. It is the gesture (in Fig. 9), in conjunction with the speech and concrete materials, which conveys the complete meaning.

It is interesting to note that Tess' approach, at some point in her probing, resembled the approach by Matt. She asked Carla to draw a 100" by 50" rectangle and imagine that there were 5-inch square tiles on the inside. Tess conveyed most of the information verbally to Carla and was unable to move her forward. Matt, however, used gestures, grounded in the materials, as a bridge to connect the information in the problem successfully.

Conclusion

Gestures can be used to interpret the thinking of all students, but may be especially useful and revealing in the case of students who are still learning academic language in English. Teachers should pay attention to the gestures where conflicting ideas are conveyed in the speech and gesture channels (e.g., making gestures for perimeter when talking about area). These differences could indicate possible misconceptions that permeate the students' thinking.

Campbell, Adams, and Davis (2007) point out that the cognitive load on ELLs is greater than non-ELLs when solving mathematics problems due to the added linguistic demands they face. In our observations, the ELLs in the task-based interviews used materials, gestures, and speech to distribute part of this cognitive load in the environment. For example, by using gestures to make reference to features in the drawings or materials, these students could create a meaningful argument without using precise academic language. By accepting and legitimizing these arguments, teachers will go a long way in encouraging the participation of ELLs in the classroom. Note that we are not advocating that ELLs should not be expected to create precise verbal arguments; instead, we see the use of gestures as a transition towards these types of precise arguments. Roth (2002) demonstrated this progression through his observations of the use of gestures by high-school students in a Grade 10 Physics course. When asked to explain the phenomena in experiments they were conducting, the students initially relied heavily on the equipment from the experiment to construct explanations. Gradually, gestures dominated their explanations as the students could talk about the phenomena without the presence of the equipment. Towards the end of the course, the researcher observed that the students were providing most of their explanations through speech with use of academic vocabulary they were learning in the course.

In addition to understanding and paying attention to ELLs' gestures, teachers can also employ gestures to make abstract content of mathematics comprehensible (Short & Echevarria, 2004/2005). Gestures can play a vital role in this process as they can act as the "glue" (Alibali & Nathan, 2007) that binds the speech and the concrete materials that the teacher uses. Given the embodied nature of mathematical ideas (Lakoff & Núñez, 2000), engaging students in concrete activities such as shading areas of different shapes to understand the meaning of 'inside of the shape' when referring to area, can provide a platform for a robust understanding of the concept. By expanding students' inputs to include gestures, teachers' understanding of student thinking increases and this knowledge can inform future instructional design. By focusing on the gestures in addition to the speech, it is possible that teachers will see ELLs' thinking at a higher level, and in turn, develop higher expectations of them.

Notes

[1]See Fernandes (2012a) for more elaboration of Vignette 1; all names used are pseudonyms.

[2]This interview was part of phase two of the project, designed to foster awareness among preservice teachers of linguistic challenges faced by ELLs and the resources they draw upon as they communicate their mathematical thinking in English (Fernandes, 2012b). Pairs of preservice teachers from a geometry content course interviewed an ELL on four NAEP measurement problems and wrote a report based on questions designed by the instructor. Later in the semester, each pair conducted another interview with a different ELL and turned in a second report.

[3]Both Tess and Matt were required to provide written reports in which they reflected on specific elements within the task-based interview, such as the language used by the student and why they made certain instructional decisions.

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Discussion And Reflection Enhancement (DARE) Post-Reading Questions:

1. How do the findings from our two vignettes build upon the framing of gestures in Moschkovich (1999)? Specifically, how do the students in Moschkovich's article differ in their use of gestures to communicate their mathematical thinking with that of the students in the two vignettes?

2. Lesser and Winsor (2009) provide an example of how an individual can use gestures to illustrate understanding of a statistical concept. With this consideration and the difficulties some ELLs face in lecture-style presentations (see pp. 17, 19 of their paper), how might you use gestures to convey the meaning of statistical concepts such as standard deviation?

3. Warkentin (2000) provides examples of how gestures may facilitate communication in a geometry class. What examples do you think would be most effective in the classes you teach and why?

4. In the conclusion, we argue that teachers should pay attention to the gestures where different ideas are conveyed in the speech and gesture channels. What specific instructional practices could you employ in order to notice the gestures that ELLs are using to communicate their mathematical thinking? Further, videotape yourself interacting with an ELL and analyze the gestures you and your student used to communicate mathematical thinking.

5. What gestures do you observe when ELLs use technology and how do they differ from the gestures used in face-to-face interactions? How might the use of technology affect the use of gestures to communicate mathematical thinking?