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The Role of Gesture in Teaching and Learning Math

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Whether we are chatting with friends, giving directions about how to get somewhere, or explaining how we solved a problem, our hands are often moving. Interestingly, while we may be conscious of the words we are using, we are usually not even aware that we are gesturing, much less that we are sending important additional information with our gestures. Although gestures are spontaneous and vary from individual to individual, they often reinforce or clarify the information found in speech, adding new information as well as nuance. For this chapter, we interview Susan Goldin-Meadow, a professor of psychology at the University of Chicago, who studies non-verbal communication with specific emphasis on gestures. Goldin-Meadow's research provides strong evidence that gestures play an important role not only in reflecting and communicating our thoughts, but also in changing those thoughts. Although her work on the topic is far-reaching, in this chapter, we will be looking specifically at the role of gesture in the development of young children's understanding of mathematics.

Background

Goldin-Meadow spent her college junior year in Geneva, Switzerland, where she had the amazing good fortune to take classes with Jean Piaget, the founding father of research in cognitive development. Piaget insisted that genuine understanding results from the learner actively constructing meaning, rather than passively accepting direct instruction from a teacher. Goldin-Meadow's interest in how children represent meaning through gesture is grounded in this theory.

Goldin-Meadow's doctoral dissertation grew out of a deep interest in where language comes from. She looked at deaf children born to hearing parents who did not expose them to sign language. While their hearing losses meant they didn't acquire spoken language, nevertheless they did construct a manual language, called "homesign," using gesture. She was interested in the ways that these homesign languages are related to, but also quite different from, the gestures that hearing people produce when they talk. That study set off an inquiry into the relationship between language, gesture, and cognition that she has continued to investigate ever since.

What the Research Says

"Mismatches" Between Speech and Gesture in Conservation Tasks

One of Goldin-Meadow's early findings regarding the role of gesture in learning emerged when she was reexamining tasks made famous by Piaget—specifically tasks that assess children's understanding of *conservation* (see Concept Box 4.1). To better understand Goldin-Meadow's research, let's first consider Piaget's classic conservation of liquid task (see Figure 4.1). In this task, an interviewer first pours the same amount of liquid into two identical short, wide glasses and has the child verbally confirm that the amounts in both glasses are equal. The child then watches as the interviewer pours the liquid from one of the glasses into a taller, narrower glass. Now looking at two glasses, one short and wide, and the other tall and narrow, the child is asked: "Is there the *same* or a *different* amount of liquid in both glasses?"

Concept Box 4.1 Piaget's Conservation Tasks

To investigate children's understanding of conservation, Piaget developed several tasks in which a substance—such as water in a glass, a ball of clay, or a line of coins—is transformed in its appearance, without changing the amount. In the conservation of number task, for example, children are shown two lines that have the same number of coins, and then watch as an interviewer spreads out the coins in one of the lines, which makes the line longer. Piaget showed that three to five year olds (in what he called the early "preoperational period") typically will say that the line of spaced coins has a different number and "has more" than the line of coins that are closer together. However, sometime between four and eight years of age, children develop the ability to *conserve quantity* over various perceptual transformations, or to recognize that the amount of a material can stay the same even as its appearance is transformed in some way. So, they are able to recognize that changing the *length* of the line does not change the *number* of coins, even though the change in spacing radically alters its appearance. Video examples of children completing Piaget's conservation tasks can easily be found online.

Typically younger children will say that there is more liquid in the taller, narrower glass. They explain that since the liquid level is higher, there must be more. Older children, on the other hand, will say that the amount of water in both glasses is still the same. Their verbal explanations show logical reasoning such as:

- *You didn't add or take away any water; you just poured it from one glass to the other.*
- *The second glass is taller, but the other glass is wider, so they are the same.*
- *If you pour water from the tall glass into the glass you took it from, the two glasses of the same size would be the same level again.*

Goldin-Meadow said that after years of showing videos of the Piagetian conservation tasks in child development courses she taught,

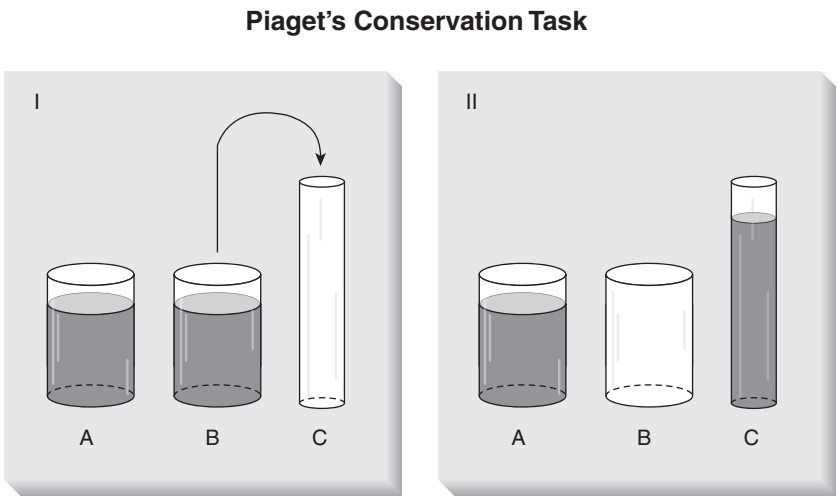

Figure 4.1 Piaget's liquid conservation task

she had an insight: "I always commented on the words that the children used [when they explained their thinking], but they also gestured like crazy, and nobody had ever mentioned it. So I started working with one of my students to code those gestures just to look at them."

She and her student, Ruth (Breckie) Church, videotaped 6 conservation tasks that they administered to 28 children between the ages of 5 and 8. For each task, they asked the children to make judgments and explain their reasoning. The researchers then created a coding system for analyzing children's speech separately from their gestures. When they compared the codes for each response, they found that some of the children used gestures that did not match the train of thought suggested by their speech.

As an example, on the liquid conservation task, a child might look at the short, wide glass and the tall, narrow glass, and say that there is more liquid in the tall glass because the liquid level in it is higher. However, that same child might simultaneously be using a gesture that indicates the glasses are of different widths. That is, he might make a "C" shape with one hand: first with the fingers closer to the thumb to indicate the narrow glass, and then with fingers farther from the thumb to indicate the wide glass (see Figure 4.2). Thus evidence from what this child *says* indicates that he is focused only on the height of the liquid in the two glasses: however, his *gestures* clearly indicate awareness of width as a second (and key) difference between the two

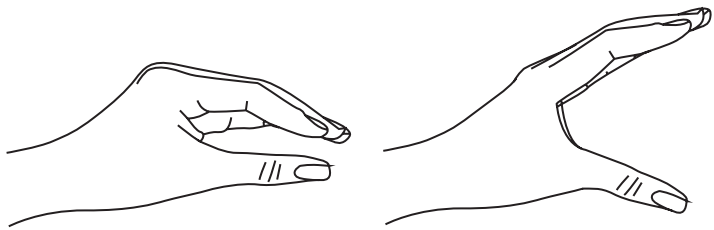

Figure 4.2 Children's gestures in Piaget's liquid conservation task. The left image is indicating a narrow glass, and the right image is indicating a wide glass

glasses. Goldin-Meadow and Church called this contrast between the understandings relayed in spoken word and gesture a **mismatch**.

Teacher Responses

- *I've seen this kind of "mismatch" happen many times with students, especially in estimation activities. Sometimes I use a "reference" jar with students to help give them something to compare to early in the year. For example, we'll have two identical jars and one will be filled with perhaps five to fifteen items, such as Unifix cubes. Students are told directly how many items are in the first jar. The second jar is then filled with double the amount of Unifix cubes, and students are asked to estimate how many it contains. I've heard students say that the second jar has only one or two more than the quantity in the first jar, even while their gestures make clear how aware they are of the very different height of the materials in the second jar. I think their gesture indicates a more accurate sense of the difference between the two amounts than they are able to convey in words.*
- *I see this kind of mismatching most often when children are switching between addition and subtraction. They will use the word "add" when "subtract" might be the better word, and they are clearly using their hands to demonstrate a "taking away" situation. I think they intuitively understand the inverse relationship between the two operations, but they are more comfortable with the idea of addition, so they default to "add."*

Mismatches as an Indicator of Readiness to Learn

Church and Goldin-Meadow's next step was to better understand why children exhibited these mismatches between speech and gesture when they explained their thinking. Church's dissertation work and

subsequent publications with Goldin-Meadow established that, across the six conservation tasks, individual children typically produced a mixture of matches and mismatches; however, some children produced many more mismatches than others. The researchers wondered whether these children might be in a transitional stage in learning to conserve. They hypothesized that children who produced a lot of mismatches might be particularly ready to benefit from instruction about conservation.

To test this hypothesis, 52 children were given a pre-test of 6 conservation tasks and asked to explain their thinking, and researchers recorded their rate of gesture-speech mismatches versus matches. All children who could not yet conserve—regardless of their mismatching tendencies—were then given instruction in conservation, and then a post-test. The authors found that children who exhibited more mismatches than matches in the pre-test showed more improvement after instruction than those with more matches than mismatches. This finding indicated that, indeed, children who exhibit more mismatches are more ready to learn than children who do not.

According to Church and Goldin-Meadow, the results suggest that children move through three stages when learning about conservation (see Table 4.1). Before understanding conservation, their verbal responses are incorrect and tend to be matched by their explanatory gestures (e.g., indicating height of water level only). As their understanding of conservation begins to deepen, their verbal responses are usually still incorrect, but their gestures often do not match their verbal explanations (e.g., showing awareness of the width of the glass). Finally, when understanding of conservation has consolidated, their verbal responses are correct and are matched by their explanatory gestures (e.g., acknowledging differences in both height and width of the glasses). In other words, when moving from pre-learning to new understanding, a child's speech and gestures may move from mostly matched to mostly mismatched, and then back to mostly matched. Thus frequent mismatches may be a key indicator that a child is in a transitional stage in thinking about conservation.

The researchers' findings support the idea that cognitive struggle is highly productive. That is, struggling to reconcile two ideas calls for more active thinking than giving a rote response that one is "sure" is correct. As Church and Goldin-Meadow examined the data from their study, as well as from studies they completed on mathematical

Table 4.1 Three stages of learning conservation

	Time →		
	Pre-learning state	**Transitional State**	**New understanding**
Few speech-gesture mismatches	Both speech and gesture tend to suggest that the child believes that transformation of container, shape, or configuration will change quantity or amount.		Both speech and gesture tend to indicate that the child understands that transformation of container or shape does not change quantity. Understanding may have generalized as a principle.
Many speech-gesture mismatches		Different information is conveyed in speech and gesture, suggesting that the child holds two different ideas simultaneously. Most often (but not always) the misconception or less abstract understanding is conveyed in speech, whereas the more advanced idea is conveyed in gesture.	

equivalence with older children, they saw evidence that children who didn't gesture, or whose gestures matched their verbal answers, usually assumed their verbal answer was correct and seldom questioned this assumption. In contrast, although the "mismatchers" often verbally expressed a wrong answer (probably the one they would have given without questioning it at all a year ago), their gestures indicated that they had begun to see the possibility that there was another way to consider the problem.

Teacher Responses

- *This finding makes me think about my English language learning students, how they often use gestures to get their meaning across. I think when I see a gesture/language mismatch there, I am often focused on the fact that the language is not correct. It makes me think: Have I missed opportunities to capitalize on what these students actually do understand?*
- *When I have my students look at images of up to eight items and tell me quickly how many there are without counting (subitizing), a majority of my students are very engaged. I do this by using cards with dots on them, arranged in structured ways that make it easy to see two sets of four dots, and asking children how many dots are on the card altogether. I can see that although they haven't ever studied the "double" fact "4 + 4" they have (or can build) knowledge that four objects and four objects put together makes eight. So they cannot say "4 + 4" but they can visualize the double. I feel like a visual number sense math talk like this gets at children's understanding of math concepts in a way that sort of circumvents what they can or cannot say. They don't have to be able to articulate it to understand it.*
- *I think with this age of children, it is natural that their gesture would be more closely tied to abstract concepts, while their language may not be there quite yet. It makes sense that the kind of thinking they can convey in gesture would outpace what they can explicitly say.*

Speech, Gesture, and Number

Goldin-Meadow found the same kind of difference between speech and gesture in work she conducted with colleagues on the development of children's early numerical understanding. Recall from Chapter 1 (Concept Box 1.1) that before children learn the cardinal principle (that the last number counted tells how many are in the set), they learn the cardinal meanings of the number words, in order, from one to four or five. That is, they learn "how many" objects the word "one" represents, then the word "two," and so on. It can take months to learn the meaning of each number word. One child might be able to link the correct number word to a set of one but not a set of two or above,

whereas another might be able to do so for sets of one, two or three, but not four or above.

In studying children who were still learning these small number words, Goldin-Meadow and her colleagues hypothesized that children might understand something about the quantities, even if they couldn't connect them with the correct number words (e.g., if they see a set of four apples, they might have some understanding of its magnitude, even if they can't connect the word "four" to it). They wondered if such children might reveal some of this numerical knowledge through gestures.

To test this theory, they first identified children who did not yet know the cardinal principle (who were still in the process of learning the meanings of the numbers one through four). The researchers asked these children to look at cards displaying small sets of objects. At first, the children were asked to indicate the quantity of each set using the number words. In another activity, they were asked to hold up fingers to show the quantity.

Overall, the children's responses were correct more often when they were indicating set sizes using their *fingers* than when they were using *number words*. They were also more accurate using fingers than with number words when approximating higher numbers (five to ten). Further, sometimes children used both a word and a number gesture at the same time, and there were often mismatches (that is, the number word and gesture were different). In these cases, the gesture tended to be accurate more often than the word. In sum, children were able to show more knowledge about the quantities with number gestures than they could with number words.

Goldin-Meadow and colleagues theorized that using gestures might have been easier due to the one-to-one correspondence between the number of fingers and the number of objects shown on the card. Number names are arbitrary, cultural conventions and therefore may be harder to remember. The researchers also believe that, in this case, gesture might serve as an important bridge between a one-to-one understanding of amount and the cardinal amount concept toward which children are building. Recently Goldin-Meadow and colleagues have found that children who produce these gesture-speech mismatches on number tasks are more likely to profit from instruction, so here again a mismatch in speech and gesture may be an indicator of readiness-to-learn.

Teacher Responses

- *Recently I saw one student use his fingers to help another student understand the number word she was using. She said "four" and held up 10 fingers. He said, "No, four is like this" and held up four of his own fingers and then counted them out for her. I think of fingers as especially useful tools for representing small quantities, and it makes sense to me that children might be able to use this type of representation before they've got their number words right.*
- *The other day, Julian was the only child left at school at the end of the day, and he mentioned this, saying, "There's just me!" I asked him, "How many children are left?" and he said, "One." Then I asked how many PEOPLE there were altogether (implying he should count the two teachers as well). He looked at me puzzled, so I changed my question to "How many teachers are there?" He answered, "Two." Then I asked, "How many people are there altogether?" and he was completely silent, but slowly put up three fingers. I think he was mentally matching his fingers to the number of people.*

Gestures Aid Young Children's Mathematical Learning

More recently, Goldin-Meadow and her associates have confirmed not only that gestures provide useful clues to children's understanding, but also that they can be a significant aid to student learning. In one study with Raedy Ping, Goldin-Meadow provided instruction to five- to seven-year-olds about conservation. The instructor modeled conservation tasks and verbalized explanations as to why the amounts were still equal even after the transformation. For example, in the liquid conservation task, the instructor might have said, "One of the glasses is taller, and the other one is shorter. But the shorter glass is wider, and the taller glass is skinnier." In addition to the verbal explanation, some children also saw accompanying gestures. For example, when stating that one glass is taller and the other is shorter, the instructor made a gesture showing one hand held higher than the other; to show the difference in width, she made a C-shape with her hand, changing its width. The researchers found that children improved significantly more on the conservation task when the instruction they received included gestures.

Note that in the experiment above, the gestures used by the teacher were designed to reinforce what the teacher was saying.

To use Goldin-Meadow's terminology, the teachers' gestures and words *matched*. Thus they were conveying the same message through two modalities. However, further research that she conducted with Melissa Singer suggested that it can be more effective to use *mismatches* in instruction, particularly when the mismatch conveys *two different but correct ideas*—that is, when the teacher expresses one *correct* idea with words and simultaneously uses gestures to convey a second, also *correct* idea (see Concept Box 4.2). The researchers speculated that expressing both ideas verbally might be overwhelming to children, whereas when one idea is provided in speech and the second in gesture, one might enhance the child's understanding of the other.

Concept Box 4.2 Goldin-Meadow's Studies on Gesture and Mathematical Equivalence

Goldin-Meadow and her colleagues have conducted a series of studies examining ways to help children learn how to solve equivalence problems such as **6+4+5 = __+5**. The researchers first identified different ideas that children draw upon in order to solve the problems, as well as how children naturally express these ideas in language and in gesture. They then used these identified expressions (speech and gesture) in instruction, to see what types of input helped children learn how to solve the problems, such as in the study with Singer, above.

The following are examples of equivalence ideas and the gestures that suggest them:

1. *Equalizer*: The idea that both sides must be equal. This can be gestured with a flat palm sweeping first under the left side of the problem and then under the right.
2. *Add-subtract*: The strategy to add all numbers on one side and then subtract the number that is common on both sides (in the above example, the 5). This can be gestured by pointing at the 6, the 4, and the left 5, then producing a flick-away gesture near the right 5.

3. *Grouping*: The strategy to group the two non-common numbers (the 6 and the 4) and indicating that these should equal the number in the box. This can be gestured by making a "V" shape with two fingers under the two non-common numbers and then pointing to the box with the index finger.

In other studies, Goldin-Meadow and her colleagues found that students learn from gesturing themselves. In these studies, they had children attempt to solve problems, explaining their thinking using gesture, before they were given a lesson on how to solve the problems. In one study, the children were just told in general to use their hands to explain their thinking. In another study, children were told to produce a specific gesture. In both studies, the researchers found that children who were told to gesture learned more from the lesson than children who were not told to gesture. Why would gesturing help the children to learn? The researchers hypothesized that children may know some information implicitly, and that gesturing might help them access that information.

Teacher Responses

- *Certainly in math I use gestures, such as saying "How many in all?" and running my hand in a circle around all the materials that are meant to be associated with a specific set. I think my conscious use of gestures is always like this, where my gestures and my language match, and both convey the same message. I don't know if I am ever "mismatching" to convey two different but correct ideas at the same time.*
- *I consistently find that children are more engaged when they are asked to use gesture along with language, like in fingerplays. The children are able to grasp concepts—often related to number—more easily when they use gesture than when they don't. We also use some gesture in regard to shape, building the shape with our hands in the air or holding fingers for the number of sides. I have seen children call upon those movements as they use language to refer to the shapes, so I think making those gestures has been helpful to them.*

Conclusion

Goldin-Meadow's extensive research on gestures touches on the full spectrum of the complex role gesture plays in the teaching and learning dynamic. She and her colleagues have found that a learner's mismatch between words and gestures seems to signal readiness to develop new understanding; they have also found that when a teacher matches words and gestures, or when the teacher uses gestures that provide additional insight that is different from the words alone, learning is enhanced. They have also found that having children gesture themselves can help them learn.

Teachers Respond to the Research

The teachers in our seminar found the research on gesture very relevant; one even said, "This validates what I've been doing all my life—lots of people tease me because I gesture so much, but this work helps me see its value." Given that most of our seminar teachers are working in schools that feature a wide variety of home language situations and that Spanish is the first language for three of them, it isn't surprising that many teachers' questions and comments were about the relationship between language learning and gesture. Teachers were also interested, of course, in how they could use gesture or an awareness of it more effectively in the classroom.

Gesture and English Language Learners

In talking about the use of gesture in their classrooms, the teachers had a lot to say about the language problems their students were experiencing as second language learners. They made remarks such as, "I think he had the idea, but he didn't have the words in English." Two of their stories are below:

- *I have become more aware of the importance of using gestures, especially in my situation, in which my students learn math in their second language. I had an experience in which children had to solve a two-step math word problem and when they first tried, they just added numbers randomly. As we read it again and again, breaking down the pieces of information one by one, and we included gestures to explain it, students became able to identify the steps they had to take to solve the problem.*

- *I keep thinking of my student Miguel whose home language is Spanish. When I ask him "How many hearts did you draw?," he counts "one, two, three, four," although there are three hearts. But when I ask him to "show me" with his fingers, he can hold up just three. So he is able to show three with his fingers accurately but can't coordinate this with the counting procedure and words.*

What is the role of gesture in second language learning, and how does it relate to gesture as an aid to developing conceptual understanding of math?

Susan Goldin-Meadow's Response

As the research presented in this chapter demonstrates, gesture is a powerful communicator and can sometimes be a better reflection of understanding than spoken language alone. In the first example above, where gesture helps English learners understand a word problem, gesture is providing an additional channel of information about what is occurring in the situation. When children randomly add numbers, it is because they do not yet understand the relationships between the numbers as the story describes them; in this case, gesture helped make the situation described in English words clearer.

There is a common misconception about math—that it is somehow not dependent upon language. In fact, many math researchers believe we could not have a number system at all without language. More importantly, mathematics has to be learned within meaningful contexts. Math only makes sense because of the ways it represents our real experiences. So for English learners who are learning to think mathematically in English, it is especially important to take the time to make sure everyone understands "the problem." Gesture can clearly be a useful tool to accomplish this.

The second example provides a clear window into the math thinking of a young English learner. Miguel knows many things: he knows that when asked "how many," he should implement a counting procedure; he knows the number words up to four and how to say them in the right order; and, importantly, he has and can demonstrate a conceptual understanding of "three-ness." By giving him a chance to express his thinking with his hands, Miguel's teacher learned about what he knows, and more importantly, what he still needs to work on: establishing one-to-one correspondence in his counting procedure

so he can connect counting to cardinal amount. Gesture is a powerful additional indicator of children's mathematical thinking, and teachers of emergent bilingual students can use it to help them.

Gesture and Total Physical Response

Several teachers mentioned Total Physical Response (TPR), a teaching strategy they have used with English language learners (ELLs). In this technique, teachers and students connect vocabulary or concepts to a specific gesture or an action. The gesture or action provides an additional cue to help ELLs (and other students as well) remember the word's meaning.

- *TPR taught me to gesture deliberately when I introduce new vocabulary words. Often, we create gestures together as a class. For example, we had a unit on equality, and were discussing segregation—a very abstract idea! I had students work with me to craft gestures that represented the meaning of the word as they understood it.*
- *When using TPR, for addition, I represent the first addend on one hand and represent the second addend with the other. Then I put my hands together for them to see how two sets come together as part of the addition process. For subtraction, I start with my hands together to represent the total as I label the idea of total, and then take one hand away to show taking away one set of numbers to find what remains.*

What are the differences and similarities between gesture consciously used as an additional form of representation, as with TPR, and the spontaneous gestures you commonly study?

Susan Goldin-Meadow's Response

I don't know much about TPR, but it sounds like gestures are used to provide an additional channel of information, explicitly matched to what is being said. It makes sense that this would be a good way to help children become familiar with English words, including math words. It also seems like creating gestures together to accompany new words and ideas would be a very powerful mechanism for learning!

Both TPR and unconscious gesturing use spoken words and gestures in concert so that the meaning is communicated in two ways simultaneously. However, the unconscious gestures may convey more complexity than would be useful in the TPR technique, which is intentionally reinforcing the match between word and gesture. Unconscious gesturing, as we have seen, sometimes conveys different additional information not found in speech.

My research on spontaneous, unconscious gestures has often led me to explore the importance of *mismatches*. I am particularly interested in cases when a mismatch is an indication that thinking is shifting, as when a child is not able to conserve verbally but seems to be aware of another way to think about the problem. Other times, as in my research on mathematical equivalence (see Concept Box 4.2), a mismatch is a way to express two different but correct ways of thinking simultaneously. Because TPR is focused on a more explicit match between speech and gesture, it may not convey as much information as unconscious gesturing can. But it seems to convey information in a very powerful way, particularly for certain learners—we would need more research to find out! Perhaps we could even get ideas for the movements used in TPR from the spontaneous gestures that teachers (and students) produce.

Gesture and Clarification

In addition to questions about gesture and second language learning, teachers began to think about their own and other adults' unconscious use of gesture. Many of their comments and questions were about the kind of communicative contexts that are more likely to bring about its use.

- *I am seeing that gesture is a valuable piece of a teaching and learning environment, and I'm not sure how much the children in my class are using it. I know that I can use it myself more, but I wonder what kind of situations might prompt the children to use gesture.*
- *After reading this chapter, I began to notice gesture among my peers. In a recent meeting, it seemed to me that other teachers and administrators were using gesture when they felt particularly passionate about what they were thinking. Gesture was especially common when someone was trying to convey something a second time—that is, they seemed to feel the first time they talked about it, they were not quite understood, so they were trying again.*

When are children most likely to use gesture? Does it often occur when they are trying to clarify a verbal explanation, or "make a point?"

Susan Goldin-Meadow's Response

Gesture that accompanies speech is definitely an indication that the speaker is thinking about what she is saying and intends to communicate. And certainly, gesture is sometimes motivated (among sophisticated communicators) by a sense that words are not enough to convey meaning without them, or that the need for effective understanding is urgent, which may be felt when a listener appears confused or unconvinced.

Anecdotally, we have seen that gestures are likely to accompany speech when something must be "re-said" because it was not understood the first time. It is not clear, however, how sophisticated an awareness of other people's minds is necessary to motivate gesture in these ways. Babies point to direct the attention of others, but that is not quite the same as using gesture as a response to confusion in the recipient of our message.

Probably the most important thing is to be sure they have many chances to try to make themselves understood. As children become more sophisticated communicators, they need moments where an adult "gives them the floor" and not only asks what they think, but also asks why they think it—in other words, the adult asks them to explain their thinking. As children get older, it will be possible for them to be listeners for each other, particularly if the conversations are structured for them by a thoughtful adult. Representing their thinking for the understanding of others is obviously a powerful learning experience, regardless of whether they gesture as part of it or not. But clearly, without a listener and something interesting to try to convey, there is no need for gesture, although we do have evidence that blind people gesture when talking to other blind people, suggesting that gesture can be for the self.

Gesture and Development

Teachers also had questions about whether there was a developmental trajectory for gesture.

- *I think some of my students are using more gesture than others, and I am wondering why. Should I be concerned? Is there something I can do to affect this or is it something that has to develop on its own?*

- *In trying to think about when and where I see children using unconscious gesture, I find myself thinking more about my older students. This is something I think I see more among my more verbal children, whereas younger children use gesture more deliberately, perhaps to direct others' attention.*

Is there a developmental trajectory for gesture that can be described? Does it seem to develop alongside language in some predictable way? Are there other factors that influence whether a child might gesture more or less? Could instruction in gesturing be helpful?

Susan Goldin-Meadow's Response

As I mentioned above, babies use pointing, often before they have any words at all. Pointing is a particularly interesting gesture, both because it has a clear meaning that can be understood based simply on context and without accompanying language ("there," or "look there," or "that"), and because, unlike many later-developing gestures, it has a specific referent in the world: an object, person, or place to whom the "speaker" wants to direct the "listener's" attention. In these ways, we might consider pointing a "less abstract" form of gesture. In early childhood, we see children begin to use their fingers to represent cardinal amount—the "three-ness" of three depicted by holding up three fingers, for example. Cardinal meaning is a very abstract concept itself, but this gesture is, again, a very specific, unambiguous gesture that requires little verbal explanation.

It's clear that at some point, gestures become a bit more abstract. In the conservation tasks we have used in our studies, when children's explanations of their thinking are "mismatching," their gestures have a particularly spatial function, as they provide a means of describing physical attributes, such as the width of a glass. Here again there is a physical referent, and the gesture, at least within the context of the experience, conveys a lot of specific information on its own. However, the ability to mismatch itself—that is, to say one thing with words and another with hands—suggests complexity of thought that probably doesn't exist earlier in development. It's also true that something like mismatch does happen very early in development. For example, when a one-word child says "mommy" while pointing at a cup to

indicate that it's mommy's cup, she is conveying one idea in speech and another in gesture, which is technically a mismatch—so mismatch can happen at a young age. And, interestingly, these types of early "mismatches" predict the onset of two-word speech in toddlers ("mommy cup").

Eventually, of course, gestures are used simultaneously with speech to provide emphasis, to allude to the co-existence of differing ideas, to mark time or sequence, and so on. In these cases, the ideas that gestures represent—relative importance, perspective, and the passing of time—are quite abstract, with little physical manifestation that can be pointed to as a referent. We do not have thorough enough research at this point to document this progression with certainty, but we see that it exists. Regarding the amount of gesture a child uses, we simply do not know what contributes to these individual differences, or even if great differences exist. I suspect that rate of gesturing varies within a person across contexts and tasks—we all gesture more when we're thinking hard about a problem. But there may be a genetic predisposition to gesture (I doubt it) or a sensitivity to gestures used by adults (more likely), or it may be a function of how much communication of any kind is in the child's environment or perhaps directed to the child. Most likely, it is some combination of all of these factors, and perhaps others that we are simply not yet aware of.

I think the kind of deliberate use of "signs" some teachers have described in this chapter sounds like a really positive use of gesture, and we know from our research that children who were encouraged to use gesture to explain their thinking learned more. I'd say that the best thing to do would be to use it yourself, use it deliberately in ways that make sense, and most importantly, encourage its use by children. It's not clear whether you can improve the gesturing itself (or even what it means to improve gesturing), but the gesture may improve children's learning.

Using Gesture to Convey Two Different Ideas When Teaching

Our seminar teachers were interested to become more reflective about their own use of gesture. In particular, they wanted more information about their own "mismatches"—when would the use of gesture to include a second message be helpful, and when might it cause confusion in students?

- *I would like more information on the idea of there being "mismatches" in instruction, such as conveying one idea with words and using gestures to convey a second, correct idea.*
- *I wonder where the line is between a gesture that effectively shows the same concept in a different way and one that confuses children. Isn't it sometimes more important that a single idea is emphasized?*

Susan Goldin-Meadow's Response

Given what we do know, and also how much about gesture we still do not understand, the best thing for teachers to do is to be aware of their use of gesture, and to pay attention to what seems to be helpful to children and what might be confusing. Most often, gestures are incidental in our experiences as learners—they are not explained by the teacher, but simply given in context without comment. This characteristic is both something that makes them powerful, and something that makes them risky. Awareness, reflection, and thoughtful use will help a teacher avoid confusing children.

Teachers' Ideas for Classroom Practice

Based on their understanding of the research, teachers had a lot to say about how an awareness of gesture can be thoughtfully used in the classroom. Below, we summarize some of the more powerful of their ideas.

Use Gesture Deliberately in the Classroom

- *I think, as a preschool teacher, I look for as many ways as possible to connect with the child: visual, auditory, and kinesthetic. I was taught that we need to give children all these experiences because in a group you have all these types of learners. So I'm connecting gesture with kinesthetic learning.*
- *Talking about gesture makes me think about how I often have students act out or draw a word problem before they try to solve it. It seems like gesture is one more way students can represent, and perhaps develop, their understanding.*
- *We use a variety of deliberate gestures, not only for math concepts, but also for things like "me too," "stop," "sit down," and "finished." Our class also has a secret code for "quiet" and we are continuing to develop signs as the children decide they are needed.*

- *Asking a five-year-old to show you what they mean non-verbally can help you understand their thinking in more depth.*

For the most part, early childhood teachers excel at providing a learning environment that incorporates physical movement. Teachers of young children know that they must manage and should plan for different levels of activity at different points in the day. Learning experiences where children dance or move in patterned ways are a common element of many preschool and kindergarten classrooms, and recess and free play are designed to—among other things—allow children greater physical autonomy than is possible during circle time or at the snack table. Early childhood "lessons" reflect these understandings when they incorporate children themselves into an activity; by acting out Goldilocks on the rug, for example; or doing a "people sort" where children with zippers on their clothes stand in one hula hoop and children with no zippers stand in another. Teachers in our seminar made a clear connection between gesture use and awareness of the value of consciously used kinesthetic activities.

On the other hand, the teachers were clear that their own use of gesture could be more conscious and deliberate. They noted its ability to provide additional information when children are learning a new word. Like many instructional strategies that are helpful for ELLs, this one is excellent for all children in the classroom. Further, some teachers are using deliberate, planful gesture to communicate beyond instances of challenging vocabulary. When the gesture for "quiet" is used by the teacher, and then mimicked by the students as they become aware of it, it becomes a silent yet participatory way for children to help each other become quiet. Their attention is gathered by the teacher and they have a more active role than "sitting down quietly" when they can make the gesture themselves to help everything along. It's a way of connecting with their teacher without talk.

Train Yourself to Watch for Children's Gestures (and Mismatches)

- *Before reading this, I did think that using gestures to teach students concepts or words could be helpful. But I didn't make the effort to look for gestures that students may be using. I think I do see students using both verbal and non-verbal skills, but my focus tends to be on the verbal.*

- *I have not really paid attention to children's gestures, and particularly have not noticed when gestures and speech mismatch. I do know there is a transitional point where a student is beginning to get a concept, and I am usually watching for clues to this; being on the lookout for mismatches may help me spot those who are ready to learn.*
- *I have always paid more attention to gesture from the teaching perspective rather than how the students are using it. I always ask myself: am I using gesture to help them understand this concept? This research makes me pay more attention to how children are using gesture to explain their thinking.*
- *This reminds me of when we were talking about where we live, and Emiliano came up to me and said, "I here" and pointed up, and added "she there" while pointing down. He's talking about the apartment building his family shares with his grandma, and saying, "I live above her." But he doesn't have the language to express it. To me, that use of gesture is replacing the words he doesn't have—it's not that he doesn't understand the concept. So by paying attention to his words* ***and*** *his gestures, I'm getting all the information.*

Learning to pay more attention to children's gestures is not easy. There is so much going on in the early childhood classroom that paying close attention to how children move their hands while they speak may be difficult to accomplish. One recommendation is to select a circle time or other occasion when you expect children to explain their thinking and to videotape it. It can be as simple as having another adult use a cell phone to focus on children's statements and gestures. Watching video such as this together can help you and your teaching colleagues become aware of different types of gesture. If, away from the busy classroom, you are able to think carefully about gestures' meanings—and notice which children are using them and when—they will become easier to spot in the middle of a hectic day.

Important Impact of Finger Use in Representing Number

- *The holding up of fingers to indicate quantity seems to me to be more of a matching activity than the verbal labeling of the set with number names. However, at some point, it seems like the fingers become sort of symbolic themselves—we just know that a hand held up with one's thumb down is "four".*

- *When I ask children how many items are in a set of four or five, and they have not mastered the skills and knowledge to count out loud and tag the objects, I often see them slowly put up their fingers. I think the children are using their fingers to match the items in one-to-one correspondence.*
- *I have also wanted to push myself to work with the children on representing quantities with different types of "formations" on fingers—so working on composing and decomposing numbers by representing five on two hands instead of one, for example.*

It is clear from this chapter that fingers as representations of small quantities are very special gestures. As Goldin-Meadow herself points out, fingers can represent the meaning of the quantities—the "three-ness" of three—in a way that the words ("three") and numerals ("3") never can. This means children have a built-in tool for telling you how they are thinking about small quantities that doesn't rely on what they are able to say! This tool is with them everywhere: on the playground, in line for the restroom, at the playhouse, at the snack table. Fingers are a powerful, flexible, and convenient mechanism for working a little bit of math into many activities.

It's also true, as a teacher above points out, that because we have two hands, we have multiple ways to express each number. We can hold up five fingers on one hand, or we can show two on the right and three on the left. Children find it fascinating that there are different ways to show "five-ness" and will want to explore every combination that makes five that they can find, once they understand the general principle. Playing "show me five" can be a great way to excuse children from the rug a few at a time, or keep everyone entertained while waiting for the bathroom. The key is to narrate and describe what children do, as in "Oh, I see you are showing four on one hand and one on the other . . . that's five too!," helping other children make the connections.

Providing Opportunities for Students to Explain Their Thinking

- *This research made clear to me the importance of allowing students to come up with their own ways of explaining things. That's the only way you can catch misunderstandings as they are happening, and since children in pre-K are limited in how much they can explain using paper and pencil—or even words—gesture seems*

like a natural way for them to demonstrate what they know and are thinking about.

- *My own experience of math learning had very little talking in it, and what talking there was mostly done by the teacher! Seeing that gesture is so connected to mathematics makes me even more sure how important it is for students to have the chance to communicate with me and with other students about their own math thinking. If I don't make it possible, it won't happen.*
- *Goldin-Meadow believes that when you use gesture to explain your thinking, you end up understanding your own thinking better. And I think that makes sense—it makes sense intuitively that if you're struggling with explaining something, and you use your hands to gesture, it helps you. It helps not just your listener, but it helps you! Between language and gesture, I think we're using both to communicate.*

As we have seen, gesture is a very powerful communicator, and not just for mathematics. It's also true that gestures—especially unconscious gestures—are likely to accompany our speech when we are struggling to communicate in words. This means, if children are to gesture, they must have opportunities to attempt to make themselves understood.

In traditional mathematics classes, children explaining their thinking was a rarity. The problem was presented, the teacher demonstrated how to solve it and explained the thinking herself, and then students silently practiced the problem type, demonstrating use of a single new strategy or procedure over and over on paper. As math educators, we have become aware how valuable it is to spend time talking together about thinking. This proves a much more powerful mechanism for generating understanding among more students, and helps to create flexibility of thought around mathematics. Students who listen to and talk about multiple ways to solve the same problem are much more likely to be able to apply strategies in useful ways, even when it is not obvious that the strategy is required.

It is also the case that this kind of "math talk" creates multiple opportunities for gesture use among children. Explaining one's thinking is never easy to do—it requires anticipating the knowledge of someone else in complicated ways. If we give children opportunities

to struggle with this process of clarifying their own thoughts so they can be understood by someone else, they will be more likely to develop as fluent thinkers. They will have practice turning their thoughts into words at a more challenging level and will learn what kinds of words make them more likely to be and feel understood. And gesture will be part of supporting this very meta-cognitive task, whether in math or in some other topic.

The Bottom Line

The idea that learners should be active agents in constructing their understanding goes back to Piaget–Susan Goldin-Meadow's first mentor. However, her research has added a significant new element to this field of study—the idea that *gesture* can play an important role in constructing understanding. She has shown that teachers obtain powerful clues about what is going on in a child's mind by paying attention to gestures, looking as carefully for those that don't match their words as well as those that do. Furthermore, teachers who support their explanations or demonstrations with their own gestures enhance their students' learning.

The beauty of gestures is that they aren't a code—they are spontaneous and often used unconsciously. There isn't a script to follow about the correct way to use or interpret them. However, they are always meaningful—and are an essential feature of how we express ourselves—especially when we are trying to communicate something that can't be, or is difficult to be, reduced to words. Teachers know that a strong signal that children understand something is that they can put it into their own words, perhaps using an example that makes particular sense to them. Goldin-Meadow's research indicates that gestures can similarly provide insight into a child's understanding.

Key Research Studies Discussed

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