Emerging research suggests that problem solvers employ distinctive gestures as they strive to explain scientific phenomena. Because the learning sciences increasingly assign explanation a central role in science learning (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Linn & Songer, 1993; Morrison, Newman, Crowder, & Theberge, 1993), distinguishing descriptions from explanations on the basis of associated gestures could prove a useful research and teaching tool. Extending the work of McNeill (1992) and others, this article outlines a way of coding gestures that allows observers to distinguish explanation discourse from other forms of science talk.

Sixth-grade science learners gesture differently depending on their discourse mode. When explaining in-the-moment, students gesture in ways that help them to predict, revise, and coordinate elements in a model. In contrast, when they describe a memorized or previously thought-out model, students time their gestures to redundantly emphasize speech. Gesture perspective, or where the speaker stands in relation to the discourse, also distinguishes descriptive transmission of knowledge from self-explanations. Whereas a describer maintains distance between himself or herself and his or her gestures, the in-the-moment explainer steps into the gesture space, assuming an inside observer perspective.

In conclusion, gesture assists in the construction as well as the communication of scientific insights.

The movements of the hands have suffered the greatest restriction through education, which tends to condemn gesticulation as undignified. (Wolff, 1972, p. 3)

Despite historical (Efron, 1941; Streeck, 1993) and academic proscriptions (Lemke, 1990), children, and even expert physicists (Clement & Barowy, 1980), seem naturally to "wave" their hands when talking about math and science (Barroso, Freedman, Grand, & van Meel, 1978; Church & Goldin-Meadow, 1986; Crowder & Newman, 1993). What purpose could this serve?

Extending Vygotsky's assertion-"thought is not merely expressed in words; it comes into existence with them" (1986, p. 218)-McNeill (1992) argued for an "active constitutive role" (p. 5) of gesture on thought, by which he meant that gesture helps to birth thought, as does language. Rescuing gesture from the semiotic sidelines, McNeill claimed that both language and gesture mediate thought. A finely tuned dialectic emerges in which thought, with its many dimensions, is both expressed and transformed by language and gesture. "There is a synthesis, and at the moment of synthesis language and gesture are combined into one unified presentation of meaning. This is an act of communication, but also an act of thought" (McNeill, 1992, p. 246).

Fundamentally, science education strives to transform thought. Scientists endeavor to understand the "whys" and "hows" of the phenomena they study, two questions that require one to see in new ways, employing semiotic tools toward that end. One tool, the
language of science, encompasses both explanation and description. Research in the learning sciences stresses the importance of learning to offer explanations to oneself and others (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Linn & Songer, 1993; VanLehn, Jones, & Chi, 1992; Wong, 1993). But description also has a place in communicating one's methods with a precision that allows peer evaluation and replication. If, as McNeill claimed, language and gesture are combined into one unified presentation of meaning, we would expect the gesture that associates with explanation and description to be distinct. This article explores how gesture may both distinguish descriptive transmission of science ideas from explanatory sense making, and serve alongside verbal language as an essential tool for sense making.

BACKGROUND

Research Context: Sense Making in the Science Classroom

This study arises out of a 3-year, National Science Foundation-funded project seeking to understand the conditions under which sense-making discussions can be supported in the science classroom. Based on the work of Kuhn (1989), Newman, Morrison, and Torzs (1993) viewed sense making as the process of explaining observed phenomena through coordination of theory and evidence.

Theberge, Crowder, and Morrison (1993) later elaborated the notion of sense making to include knowing the culture-specific rules for "combining, seeking, and interpreting both experience-based and authority-based knowledge" (p. 6). In the classroom, as in the scientific community, the work of theorizing is socially supported—findings are successively refined as they are aired in a community of peers for feedback, and models are built and run to test, at least partially, the explanatory power of theories. This last sense-making activity, building and running models, is the primary focus in this article.

Science Talk: Explanation Versus Description

Sense making and knowledge transmission are subsets of generic science talk (Figure 1), a discourse register used by speakers in the context of science (Cazden, 1988; Lemke, 1990). Transmission and sense-making talk differ in the stance they take toward science. Someone transmitting science views it as an object to be talked about. In contrast, science for the sense maker is the action of coordinating theory and evidence, and developing reasonable models of that coordination. Transmission talk emphasizes transference of ideas and prior discoveries from one person to another, whereas sense-making talk mediates the collective explorations, experimentations, and coordinations involved in active discovery. The overlapping zone between the two science talk modes allows students to incorporate learned facts into hypotheses and adopt tried experimental methods as a guide to exploration.

The current literature on spoken and written science talk has defined its abstract ideal form (Lemke, 1990; Michaels & Bruce, 1989), examined the challenges posed to nonnative speakers of English (Rosebery, Warren, & Conant, 1992; Spanos & Crandall, 1990), and exposed alternative discourse styles that might mask fundamental scientific understandings (Michaels & Bruce, 1989). The classroom teacher who seeks to promote sense making must first recognize sense making in her students' science talk. This is not always easy, because students have been well socialized into the standard question-answer format in which teachers highly value students' right answers (Cazden, 1988; Lampert, 1990).
In general, students introduce models into the classroom discussion in two strikingly different ways. Many students assert their beliefs in the smooth coherent style that we interpret as either illustrating a model that has been learned from an authority (e.g., reciting the "correct" answer) or as authoritatively describing the results of prior thinking and modeling. Other students employ a different speech pattern, however. They present their ideas with multiple stops, starts, and revisions, both verbal and gestural. Crowder and Newman (1993) suggested that these unpolished performances may signal that students are involved in actively constructing knowledge, running models to help them in this process.

Prior Research on Gesture in the Science Classroom

Our project first reported on gesture in Crowder and Newman (1993). We found that representational gesturesfunctioned in three ways—as redundant to ideas expressed through speech, enhancing of them, or as an alternative carrier of scientific meaning. As long as ideas outstrip scientific vocabulary, one can expect to see gestures used by elementary science students to carry unstated ideas. Another pattern, characterized by a gestural-lexical interplay called interwoven gesture-talk, seemed to suggest that gesture might serve more than a communicative role. It may reflect imagistic thought and help shape subsequent language. Clement and Barowy (1993, p. 20) offered evidence that gesture may reflect thought by revealing its intimate linkage with the active running of models (p. 12). Their informants gestured primarily as they predicted outcomes of a
system's behavior (1993, p. 21). Typically occurring just prior to solving the problem, the gestures they observed coincided with a tendency for participants to look away (from the interviewer) or fixate their gaze. These researchers therefore concluded that their participants' gestures were not simply intended to communicate with the interviewer.

Starting from the initial observations reported in Crowder and Newman (1993), this article continues the search for consistent categories of gestures that could contribute to a finer grained analysis of sense-making discourse. The earlier article noted several styles of gesturing that I have selected as the basis for developing the present units of analysis. One prominent pattern in the classroom talk described previously (Type I, or gesture-redundant talk) was characterized by speech-timed gestures, whereas the verbal line carried the content of the argument. The gestures used in gesture-redundant talk were often redundant to the verbal message, as the name implies. Another pattern (Type 4, or interwoven gesture-talk) alternated speech with gesture, and the verbal content often changed as a result of gesturing (see the Appendix for a full description of lexical-gesture types).

Research Questions

This study seeks to describe the types of gesture and perspective taking associated with two of many possible language activities in science talk. It asks the following questions:

1. What types of gestures distinguish the following two language activities in sixth graders? a. descriptive talking about scientific ideas b. explaining through actively running models
2. In what ways does student perspective taking coincide with describing and explaining?

To answer the research questions, my first task was to develop a finer grained description of the gestures that pattern with these two forms of science discourse. I proceeded by first developing verbal-gestural transcripts of the six illustrative performances, recording how gesture associated with language and discourse behaviors such as hesitation phenomena. Gestural analysis focused on noniconic gestures as the best source of clues for sorting model running from model describing (see McNeill, 1992, for the role of beats in signaling shifts among different levels of narrative-narrative, metanarrative, and paranarrative). A set of noniconic gestures present during explanation but absent during model description were identified and described.

METHOD

For the larger study of conditions that encourage scientific sense making, we observed sixth-grade classrooms in the following locations: two attached classrooms in a school in Hillsborough, a predominantly White, middle-class suburb of Boston; two classrooms located in an ethnically mixed alternative school in Riverside, near Boston; and two classrooms in an inner-city "minischool" in New York City, serving a primarily African American population. The participating teachers helped design a unit on shadows and seasonal change that included both manipulation of props and data collection. During the focal lessons, students constructed models, used props, or enacted the changing earth-sun relation as shadows change length or as seasons progress from winter to spring, summer, and fall.

The data presented here comes from one lesson in each of the three locations (a total of three different lessons). In these lessons, students either describe or explain their idea of a model as they answer questions posed by their teacher. Teachers in the Hillsborough and Riverside classrooms asked their pupils to answer the question "What makes the seasons change!" then to pantomime their understanding of how seasons change. One student was seated in the center of the room, whereas others took turns enacting their ideas. Teachers initially prompted students to actually "become" their
model, assuming the role of the earth as it moves around the sun by physically moving their own bodies around the seated boy-sun.

3We have given the towns pseudonyms.
4A group of seven teachers formed a minischool within a New York City public elementary school to which students apply for acceptance. Students in the program benefit from smaller class sizes, frequent access to networked computers, and special ongoing activities such as student-run newspapers and videotaping.
5The accepted theory of seasonal change asserts that the earth maintains a tilted axis relative to its plane of orbit around the sun. When the North Pole tilts away from the sun the South Pole tilts toward it, causing rays to strike most directly just below the equator, longer days in the south, and a southern Summer. Fewer rays striking at an acute angle must illuminate a larger area in the north. Less energy covering more area, combined with shorter days, drops the seasonal temperature 10° to produce a northern winter. The earth continues to orbit the sun as the year progresses, maintaining a fixed tilt toward the north star. As it orbits 90° away from north-winter and south-summer, neither hemisphere is tilted away. The transitional seasons of spring (north) and fall (south) result. Continuing to orbit, the earth travels 180° from its starting point, and the southern hemisphere now angles away from the sun, the north toward. Seasons in the two hemispheres have been reversed to north-summer and south-winter, and the cycle continues.

Although the Riverside lesson occurred approximately halfway through the year-long unit, data collection had been assigned to only a few "capable" students in this class, so the majority of students had had little hands-on experience with actual data. During this lesson, students were asked to give their "theory" of how the seasons change. The students came to a table at the center of the room and presented their ideas using a globe. Theories ranged from close approximations of the accepted tilted-earth and angle of the sun's rays theory5 to a static view that seasons are placed in four quadrants on the globe or that seasonal bands encircle the globe. The dominant argument among Riverside students centered on whether four or two seasons exist at once.

The New York City students addressed a slightly different problem from the more general one raised in Hillsborough and Riverside. Near the end of their unit, these students had already spent considerable time measuring the changing patterns of shadows throughout the day. A question raised by these explorations had most recently occupied their discussions-Are shadows the same or different lengths at the same time of day for the same-height object placed in different spots around a playground? Fresh from an experience involving measuring 20 cm sticks lined up on the playground, after which they decided as a class that the shadows would be "the same," the students addressed a new "street light" problem. In their class auditorium, one of the researchers and the teacher set up a light on a step ladder 2 m above the floor. Starting 1 m from the base of the step ladder, the students spaced their 20 cm sticks 1 m apart in a straight line. The teacher then asked whether the shadows cast by the dowels, illuminated only by their rigged-up streetlight, would be the same or different lengths. Three students asserted three different opinions-The shadows will be the same (a view espoused by Quinton); longest for the farthest stick (Malik's argument); and shortest for the farthest stick (Hameel's belief). Both Quinton's description and Malik's explanation will be reported here.

**Method of Analysis**

*Type of Engagement in "Science"*

For this article, I analyzed six performances of children that had been previously coded as either *describing a model* (or event), or *running a model* (Newman, Crowder, & Theberge, 1992). For each of the three lessons, I identified a pair of students who spoke about related subject matter (a total of three pairs). Two students from Hillsborough illustrated the acts of describing a model and running a model, respectively. From the Riverside setting I selected two students, one who described a previously thought-out
argument and another who explained while publicly constructing and running a model (Gail). And finally, from the New York City classroom, I chose Quinton, who described the method used to perform an experiment, and Malik, who actively constructed a model.

For the first two pairs, two researchers independently judged one of the pair to be a *describer of models* and the other a *runner of models* who used dynamic models to help explain or construct new ideas (100% agreement). A third pair differed from the first two in that the "describer" student told stories about the "way things had been done" in a previous class. Instead of describing a model, he compared an earlier playground shadow measurement class with the experimental set-up laid on the floor before him. This student's more narrative description allowed comparison of gestures used in describing a model versus describing in a more general narrative sense (storytelling). In all six cases, two raters agreed that the students were describing a model, running a model, or storytelling.

To check validity, a group of Bolt Beranek and Newman, Inc. researchers viewed portions of my video data, engaging in a method of video analysis termed interaction analysis (Jordan & Henderson, 1995). As group members volunteered their observations, the distinction between the terms describer of models and runner of models was verified. The researchers to whom I presented my data articulated the distinctions in this way:

**Describer of a Model**
- is teacherly
  - demonstrates an understanding
  - can perform one's understanding
  - communicates that one already understands
  - gestures more for the audience

**Runner of a Model**
- is figuring things out
- publicly constructs understanding
- revises and repairs understanding
- communicates being currently in the process of understanding
- gestures more privately

Although I selected contrasting pairs of students from each classroom, I will organize my results and discussion section according to three discourse categories: (a) gestures used while describing, (b) gestures used while explaining models, and (c) perspective taking while describing or explaining.

**Explanatory Codes**

In addition to the two categories, describing a model and running a model, the speech and gesture in each transcript were coded for explanatory style as described next. This allowed specific process gestures to be connected with explanatory function.

- refers to a *static* model
- initiates running a model
- relates two elements in a model
- refers to a *dynamic* model-a model moves or things change in relation to each other
- predicts from model
- verifies prediction
- revises and repairs statements or predictions

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6 It is important to note that the understanding demonstrated may not be "correct" with respect to conventional theory. However, the speaker assumes a stance that is.

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One final paralinguistic code characterized the speaking style of the students in the data:

- hesitates verbally
Preliminary analysis identified noniconic gestures as the most likely to distinguish description from explanation. In addition, previous work (Crowder & Newman, 1993) suggested that different speech and gesture patterns might also distinguish these two forms of science talk. In one pattern—gesture-redundant talk—verbalization carries the content, and gestures are timed to mark emphasis. We now explore whether this pattern associates with description. In interwoven talk, speech and gesture alternate, and speech often changes in response to prior gestures. This pattern might well associate with explanation (see the Appendix for a full description of speech/gesture types).

In coding data, I used both the system established by McNeill (1985,1987,1989, 1992), which characterizes the concreteness or abstractness of gestures, and the functionally based distinctions developed by Crowder and Newman (1993). Briefly, McNeill’s gesture types span a continuum from maximally representational to nonrepresentational. The separation into content and process gestures is mine:

Content-oriented:
1. iconic: gestures representing concrete attributes, actions, or relationships between objects or characters
2. metaphoric: gestures representing abstract content or abstract images
3. deictic: finger points or other indications toward concrete or imaginary objects or people

Process-oriented:
4. beats: two-phased movements, made with formless hands, that convey no information, but instead move in rhythmic relation to speech
5. Functional gestures. The Crowder and Newman analysis scored individual gesture-speech pairs (gestures and any co-occurring speech) as 1) redundant, (2) enhancing, and (3) content-carrying.

Content-oriented:
1. Redundant gestures are those that add no new information to that already expressed in accompanying verbal language. Many redundant gestures point to a prop or present an icon that matches a content word (e.g., a circling motion accompanying “around”).
2. Enhancing gestures extend the meaning of the language in some important way. For example, instead of pointing to the hemisphere receiving direct sun rays, the child might shape a hand in a flattened 0 position, suggesting concentration of the sun's rays.
3. Content-carrying gestures contain unspoken content. For example, a child might never say “symmetrical,” but still gesture with both hands, portraying temperature bands on either side of the equator, thereby revealing his or her knowledge of symmetrical hemispheres.

Process-oriented:
4. Model adjusting gestures change the position of the model, adding to an explanation or synchronizing it to the speaker’s conception of the correct
relationships. For example, one girl adjusted the direction of the tilt bar of a globe circling the sun to keep it pointing in the same direction.

5. Paragestures reveal the speaker's attitude about some aspect of the communication, not content or process (e.g., a shoulder shrug).

6. Pause-filling gestures occur during silent pauses (e.g., "I think it will be [traces sun-to-earth path twice] about here.").

7. Speech-timed beats are nonmeaningful, emphatic gestures that are timed with speech (e.g., "It will be [up-down beat] here.").

8. Preparatory movements prepare a model for use, adding no new meaning (e.g., a student slides a globe toward himself).

9. Gesture pauses are periods during which the speaker ceases to gesture, dropping his or her arm to his or her side.

Analyzing Perspective and Discourse Structure

Performances were also coded with respect to perspective (McNeill, 1992, p. 192), defined as "where the observer stands," either inside or outside of the gesture space. To inside observer perspectives I add participant perspective, which reflects how students in my data sometimes assumed the role of an object in their model. It incorporates the essential feature of bodily enactment or reenactment.

Thus, the three codes I use to describe perspective are as follows:

1. Participant-The communicator moves as if he or she is an element in the model being described or explained. Whole body movements, self-touches, or making one's body the central reference point characterize this perspective (see Figure 2).

2. Inside observer-The communicator remains an observer of the model, as revealed by manual rather than bodily representation, but places him or herself physically within the gesture space, approaches the gesture space, or keeps hand motions close to the body (see Figure 3). Eye gaze is often toward the gestures.

3. Outside observer-The communicator remains an observer of the model, maintaining separate gesture and body spaces, or distances self from the communication act through paracomments or paragestures. Eye gaze is often toward the audience.

EXEMPLARS FROM CASE STUDIES
This section compares gestures students use to explain with those used to describe. In the introduction, I noted that unpolished performances-marked by stops, starts, and revisions-may signal students’ active construction of knowledge. However, if we are to distinguish the stops and starts associated with running a model from those marking mere uncertainty, we must further characterize the gestures that accompany these hesitations. In this section, we look closely at the form and function of gestures associated with description and explanation, so the two may be distinguished more precisely.
FIGURE 2 Participant perspective --

Ivan complies with the teacher's request to use his body as his central point of reference: "Which side of you is cold? Which side of you is winter?" By pointing to his back, his body participates by "becoming" the earth with one of its sides in winter.

FIGURE 3 Inside observer perspective--

Ivan places his body within his gesture space while maintaining a clear external referent as he points to the sun outside his classroom window: "This side is hotter because the sun has... and as it goes around it also kinda tilts," Note that "tilts" coincides with a switch to participant perspective.

**Gestures Used While Describing**

Fifth and sixth graders used the following gestures and verbal and gestural patterns as they described a model of seasonal change or light and shadow relations:
1. undifferentiated process gestures—emphasized verbal description of models
   a. simple points—simple open-handed or index points; clarified and redundantly emphasized speech
   b. speech-timed beats—coincided with sentence stress; serve to set up narrative contrasts
   c. pause-filling beats—marked time in pauses
2. eye gaze—directed more toward audience than toward gestures
3. frequency—gestures less frequent
4. timing—gestures accompanied or followed speech
5. outside observer perspective—gesturer remained outside the gesture space
6. speech—communicator spoke fluently with less mid phrase hesitations.

**Infrequent Use of Gestures**

Jake provided an example of infrequent use of gestures. During the Hillsborough lesson, several students asserted that winter and summer change as the earth faces toward and away from the sun. Jake had a different view, though he did not overtly assert how it contrasted with the views that had gone before. He believed distance from the sun governs seasonal change. Walking quickly around a boy seated in the center of the room, who represented the sun, Jake told us that as we on earth orbit farther from the sun, our seasons turn colder:

Jake: (off camera) Like the earth goes—

Jake when it’s spinning around, it gets farther from the sun, 
body: [walks quickly around the 'sun' while spinning]
gestcode: redundant, whole body 

Jake: and it gets colder way from the sun.
gest: [at hip level turns both palms up, as if saying "of course"]
gestcode: paragesture

Jake: It goes around and in the summer it's like this and then in winter it goes round.
gest: [walks a second orbit around the sun]
gestcode: content-carrying, whole body

Teacher: It goes farther away from the sun in winter

Jake: yea 
gest: [shrugs hands, palms up at hip level, as if saying, "it's simple"]
gestcode: paragesture

Jake employed only two manual gestures throughout his version of the earth and sun relation, both of which are paracomments on the obviousness of his statements. His whole-body reenactment of the earth's path coincided with and was at first redundant with his speech. His description of the location of the sun for summer compared with winter lacked explicitness, forcing his pantomime to carry the meaning. Jake left it to the teacher to overtly give voice to his actions.

By saying "when it's spinning... it gets farther... and it gets colder," Jake related the elements in his model in time. Jake communicated that "when" certain conditions exist, other properties like cold exist as well. The physical states are associated with the position of the earth relative to the sun, but not related through causal mechanisms: "It goes around and in the summer it's like this and then in winter it goes round."
his model as a statement of fact; he did not appear to be actively explaining to himself or to others by manipulating the model.

I took Jake's performance to be a description of his understanding of a model, one that either summarized as fact something he had already thought about or reported what he had learned from a book. He was neither trying to figure out what he thought nor was he trying to help someone else understand. Although we could not discern his main purpose based solely on this performance, preinterview data revealed that Jake had previously thought about his model in a "working it out" mode, so in this case, Jake was probably summarizing prior thinking.

**Descriptive Gestures Are Speech Timed**

Another student best illustrated the stress-timed nature of gestures used to describe a model. Erma employed a globe rather than whole-body pantomime to convey her ideas. She too had previously thought out her ideas. She revealed this by asking if she and another student, Gail, could present together. Evidently her portion of their planned presentation was to have been to argue that only two seasons occur at once, a statement of the "way things are" rather than an active "running of a model"

Erma: Okay, I think, that when it's summer in the north,
gest: [hand poised] [left open hand placed on northern hemisphere on "summer"]
gestcode: redundant, deictic

Erma: it's winter in the south.
gest: [hand placed on southern hemisphere on "winter"]
gestcode: redundant, deictic

Erma: but I think that the closer you are to the equator

gest: [pulls globe closer to self and looks at it]
gestcode: model prep

Erma: the warmer it is. no matter whether it's summer or winter. [looks at teacher (audience)]

Erma: I think that when it's spring in the north,
gest: [places left hand on north hemisphere on "spring"]
gestcode: redundant, deictic

Erma: it's fall in the south.
gest: [places both hands on southern hemisphere on "south"]
gestcode: redundant, deictic

Erma: OK?

Erma: I think that- , I I don't think that, there, there are like four seasons at once,
gest: [briefly and loosely flashes four fingers and rolls them into a ball on "four"]
gestcode: redundant, iconic

Erma: I think it's either summer,
gest: [touches northern hemisphere on "summer"]
gestcode: redundant, deictic
Several things were striking about Erma's gestures and her use of gesture space. First, she pointed with her whole hand rather than embellishing her gestures with shapes that add meaning. Second, Erma punctuated her assertion that only two seasons exist at once with speech-timed pointing to the appropriate hemisphere. Her pointing usually coincided with the word that receives the greatest stress in the sentence. This time congruence between speech and gesture might have reflected Erma's certainty of her ideas, or at a minimum, an awareness on her part of her unfolding public performance.

We see similar speech timing employed by a student at the New York City school. In a "streetlight" experiment, the students had been asked to predict whether the shadows cast by a line of 20-cm sticks using a streetlight as the light source (actually a light bulb hung from a ladder) would get longer as the sticks got farther away, whether they would be shorter, or the same. The two classes had previously had experience measuring shadows cast by a line of 20-cm sticks on their playground, using the sun as the light source. Many but not all of the students correctly remembered that the shadows in this instance were of equal lengths. Quinton was among those who remembered this experience, and he invoked it as he justified his belief that the shadows would be of equal lengths.

In Quinton's subsequent performance, he did not describe a true model. Rather, he drew an unanalyzed analogy with prior experience. He did, however, inform us: "I think this way"—a marker signaling that the speaker is likely to give a description rather than an explanation. As Quinton presented his analogy, he motioned with gestures we had been associating with description. He reminded the class of the similarities between the current experiment and the one performed on the playground, employing a narrative form punctuated by up-down beats timed to his words, the same speech timing we saw with Erma. His performance differed from Erma's in that his gestures thus far carried little meaning, whereas Erma's contained deictic reference. He also frequently gave his hands a rest, clasping them in front of himself:

Quinton: Well,

Quinton: (silent)

gest: [on silence swings arms together in front of body and clasps hands]
gestcode: gesture pause coincides with verbal pause

Quinton: I think this way, they are all going to be the same,
gest: [swings arms out away from body, waves hands four times one each word "all," "going," "be," and "same," then sweeps hands toward center]
gestcode: 4 speech-timed beats

Quinton: because we- outside

gest: [(going toward neutral) clasp hands again in front of body on "because"]
gestcode: gesture pause

Teacher: xxx [10 The xs denote inaudible speech]
Quinton: (louder) I think they are all going to be the same because,
gest: [neutral, standing with hands still clasped]
gestcode: gesture pause

Quinton: outside we did the same experiment
gest: [arms out to sides, beat on "experiment"]
gestcode: speech-timed beat

Quinton: when we were all spaced out,
gest: [three beats on "all," "spaced," and "out"]
gestcode: three speech-timed beat

In silence, Quinton then repeats several bounces as he indicates the sticks spread out in front of him:

Quinton: (silent 1 sec)
gest: [left hand bounces three times along row of separated dowel sticks]
gestcode: redundant, follows speech, deictic

Quinton: and we had the same dowels thing,
gest 1: [sweeps hands in toward center on "same"]
gest2: [bounces hands twice just after "dowels" and "thing"]
gestcode I : metaphoric: sweeping motion represents equivalence
gestcode2: speech-timed beats

Quinton: and we measured the same, an

gest: [sweeps index finger up and down row of dowels ending with alternating bounces of hand (one on "and" and the next on silence after)]
gestcode: metaphoric: sweeping motion represents equivalence
gestcode: speech-timed beat (superimposed):

At this point Quinton pauses, bouncing his hands up and down in the beat-like motion called "pause-filling beats." The beats at this point appear to signal a shift in Quinton's scientific narrative—he switches from describing method to summarizing results:

Quinton: (silent)
gest: [index beat]
gestcode: pause-filling beat

Quinton: and mostly xxx some xx
gest: [sweeps hand down row of sticks left to right with hand bouncing]
gestcode: metaphoric = equivalence

Quinton: rounded up
gestl : [hands outstretched right hand beats on "rounded"]
gest2: [beat placed higher on "up"]
gestcode 1: speech-timed beat
gestcode2: speech-timed beat with some iconic elements

Quinton: they went to the same <point> and-
gest: [arms outspread, continued fast repetitious beats, not syllable-word timed here]
gestcode: beat
Quinton employs an additional pattern typical of description but not model running when he gestures after related speech. The three beats that emphasized "all spaced out" continue, when he pauses, in the form of meaningful bouncing points, conveying that "the sticks were spaced out like the ones here on the floor."

**Gestures Used While Explaining a Model**

Fifth- and sixth-grade science students used the following gestures and verbal-gestural patterns as they explained and ran models of seasonal change or light and shadow relations:

1. deictic and beat-like process gestures performed work in science discourse
   a. sighting-eye gaze linked parts of a model; coordinated parts
   b. retracing beats-partially traced and retraced a motion, suggesting initial moment of running a model
   c. tracing points-traced whole pathways, lending dynamic quality to model and helping to predict or verify predictions
   d. resolving points-started from general vague hand shape and resolved into index point in the process of verifying predictions
2. eye gaze--directed more toward gestures
3. gestural foreshadowing-gestures often preceded related verbal meaning
4. inside observer perspective-gesturer stepped into the gesture space or model
5. model adjusting-gestures used to adjust or revise components in an overt model, seemingly to make it conform to an inner model of observed phenomena; shows meta-awareness of model inadequacies
6. speech-communicator spoke nonfluently, with numerous verbal and gestural hesitations

**Gestural Foreshadowing**

When meaning-carrying gestures precede speech representing the same meaning, gestural foreshadowing has occurred. Such foreshadowing reveals an active engagement with the content. In the next example, Gail was trying to decide where the sun would shine most directly, given the configuration of the model she had constructed. Just prior to the excerpt provided, Gail had said the sun, represented by her left fist, was shining "right, about, straight on the equator." She then checked this statement by tracing a line from her "sun hand" to a globe in front of her, revising her statement in the process:

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gest: [right hand begins tracing line toward globe]
Gail: (silent)
gest: [completes line from sun to earth, heading for just below equator]
Gail: no, right about here. More on the, ... southern hemisphere. Shining directly about over, somewhere over here. [see Figure 4]
```

In the preceding excerpt, Gail repeatedly interspersed her gesture with language as she explained the seasons in a back and forth interplay that continually refined meaning. Her timing contrasted here with that seen for students who were describing relations-Gail's gestures preceded rather than coincided with verbal consequences.

**Beats, Points, and Eye Gaze With Special Functions**

Children who explained a model, instead of describing it, gestured in distinctive ways. Their deictic points and beats, marking important moments in the discourse, tended
to trace pathways in a model, retrace those pathways or some other previous gesture, and resolve from a loose-handed deictic reference into a more precisely articulated point. Some of these beats and points were associated with distinctive forms of eye gaze.

**Eye gaze--Sighting and averted gaze.** Eye gaze appeared to serve two functions for the students observed. The first, sighting, was more directly related to doing work with and within a model. It was characterized by eye gaze from one part of a model to another and associated with coordinating two elements of a model into a whole.

![Diagram of Gail gesturing](image)

**FIGURE 4** Gail gestured, then revised a verbal prediction: "No, right about here. More on the, ... southern hemisphere. Shining directly about over, somewhere over here."

A second type of eye gaze, gazing down or away, is discussed in the section dealing with perspective. Sighting eye gaze often preceded manual tracing gestures, seemingly in an effort to connect the two into a coherent system or to check the accuracy of the model as it was run. Malik, in the next transcript, provides an example of sighting:

```plaintext
Malik: if the sun is (lengthened) di
gest: [looks up on "sun"] [left loose hand bounces on "sun" then stops up next to his head on lengthened "is"] [beat on "di-"]
eye gaze: eyes up
Malik: xxx <part xx> it would be (1 sec)
gest 1: [right hand beat on ",part>" toward floor and dowel] 2 [moves 'sun' hand to behind head]
Malik: uhm
gest: [sights from hand to dowel]
eye gaze: sighting
verbcde: filled pause
expl: relating two elements in model (gest)
Malik: <There'd be> xxx
gest: [right hand starts tracing line from sun hand to stick, body continues along trajectory toward stick, L hand stops being the sun and starts to point at stick before interruption from teacher]
gestcode: tracing gesture that carries meaning
expl: relating two elements in model (gest)
```
Teacher2: Talk to the camera.

Malik: the rays are gonna be ..,
gest: [looks at camera]
eye gaze: eyes toward audience

Malik: (silent)
gest: [kneels down close behind a stick]
Malik: hitting off the top.

Retracing beats. Retracing beats were characterized by arcing, two-phase motions, associated with the initial moment of running a model or with the introduction of new elements into the model. Using this device, Ivan signaled that he would begin representing the earth's year as it revolves around the sun:

Ivan: well, anyway, as the earth (rise in pitch)
gest: [swings hand from a spot in front of him in short counterclockwise arc and returns to spot in front of him]
gestcode: beat, retracing
expl: initiates running a model
Ivan: turns around the sun,
gest: [index extends and traces full counter clockwise arc suggesting motion around seated sun]
gestcode: iconic, redundant, dynamic
persp: outside observer-Ivan places himself outside of the gesture space.

When he signaled he would run the preceding model, Ivan used a deictic gesture overlaid with a retracing element. Retracing beats may be superimposed on a number of other types of gestures, both manual and whole body.

In the next example, Ivan retraced a whole-body movement as he introduced a new idea into his performance, the notion of tilt. He had just finished describing the motion of the earth around the sun. At this point he paused in his whole-body movement around the sun and brought his hands in front of him, as if to hold the earth. He raised one arm slightly and then began a whole-body motion that repeated three times:

Ivan: you could say,
Ivan: (silent)
gest: [steps once forward maintaining arms tilted]
Ivan: kinda ...

Ivan: (silent 4 sec)
gest: [bends body at waist 3 times toward sun, maintaining arm posture]
gestcode: iconic, retracing element superimposed (whole body)

Ivan: tilts this way.
gest: [third bend coincides with "tilts" and body posture shifts so that left side is tilted toward the sun]

Tracing points. Tracing points are characterized by gestural tracing of pathways. They could be associated with the notion that a model is dynamic, as Ivan illustrated:

Ivan: turns around the sun,
gest: [index extends and traces full counter clockwise arc suggesting motion around seated sun]

gestcode: tracing, redundant,

expl: dynamic model

Malik's sighting transcript also illustrates a frequent temporal relation between sighting and tracing points (see also Figure 4). That is, visual sighting is frequently followed by manual tracing. However, tracing can occur without prior sighting.

Tracing gestures may accompany speech or verbal pauses. They also may be associated with predicting, verifying, or revising a prediction. For an example of tracing that takes place predominantly during verbal silence, we look again to Gail. She traced to verify her verbal prediction, revising when she discovered the relation among elements in her model differed from her expectation (Figure 4):

Gail: now right now, it's- (takes a step off camera)

Gail: it would be shining (2 sec pause)

gest: [Loose, dangling right hand comes into view]

Gail: let's see. Over-, right, about, straight on the equator

gest: [2 beats on "right" and "about"]

Gail: (overlap with "equator")

gest: [right hand begins tracing line toward globe]

gestcode: tracing, redundant

expl: verifying a prediction

Gail: (silent)

gest: [completes tracing line from sun to earth, heading for just below equator]

gestcode: tracing, content-carrying

expl: revising a prediction (gest)

Gail: no, right about here

gest: [hand taps globe a little further below equator (2-3 inches)]

gestcode: deictic, content-carrying

expl: revising (verbal)

Gail, concerned as she was with precise placement, revealed that she considered the elements in her model to be in meaningful relation with each other. Their relative placement was relevant to her overall explanation. Note also that the revision manifested first gesturally, then verbally.

Resolving points. Resolving points are characterized by a general, often vague hand shape that first locates a general area, becoming more definite as it resolves into an index point. This gesture is associated with verifying a prediction and seems to signal final decision making. The next example, drawn from Gail's performance, follows the revision quoted in the Tracing Points section. In that quote, Gail ended by tentatively committing to a location where the sun's rays shone most directly on the earth (given her model) in her verbal line. As she verified this revision, she indicated initial tentativeness through both words and her loosehanded gesture. The tentativeness soon gave way to a more definitive point, indicating she had made a decision:

Gail: shining directly about over,
gest: [quick circular movement with index on "about"]
gest: [on "over" twists hand as if turning something]

Gail: somewhere over here..
gest: [repeatedly circles hand with its back touching the globe on "somewhere"]
gestcode: deictic, content-carrying,
expl: predicts

Gail: (silent)
gest: [continues with circling but resolves hand shape into an index point-- circles twice, then stops before speaking again]
gestcode: resolving point, deictic (open hand to index point)

Gestures at Work

Now that I have defined the specialized beats and points associated with running an explanatory model, I would like to illustrate how these gestures work together in the flow of discourse. Malik provided a concise example of process gestures. He first set his argument in opposition to Quinton's, who believed that all of the shadows cast by a streetlight would be of equal length. At the teacher's prompting, Malik stated his position as an opinion, though he included a gestural-verbal mismatch by saying that the "longer" sticks would have longer shadows, when what he really seemed to mean was that the "farthest" sticks would. Despite the mismatch, he made himself understood to the teacher, who restated Malik's idea for the class.

IICassell, McNeill, and McCullough (1993) explored how listeners interpret speakers who fail to match gestures with their speech. They found that context plays a part in determining which meaning the listener chooses to attend to. In support of their findings, Malik's teacher incorporated Malik's "farther" gesture into his representation of what Malik was intending to communicate, possibly helped by the fact that it fit with his own understanding of the streetlight phenomenon.

Malik: I think that the longer ones
gest: [pointing to sticks farthest from ladder]
gestcode: deictic, content-carrying, mismatch (longer-verb vs. farther-gest)
expl: expressing opinion outside observer

Malik: gonna have a longer shadow and the shorter ones <shadow gonna be ***>
expl: predicting (verbal)

Teacher1: so the ones up here closer to the light bulb are gonna have shorter ones and the ones further away are gonna have longer ones. Do you wanna say, anymore about why you think that is? Lenny, I hope you're listening.

Next, Malik ran his model to support his argument. He signaled this by beginning with several hesitations, stops, and starts and upward eye gaze as he located a hypothetical sun overhead, then predicted where the shadow would be, given that position. We suspect that he might have been having trouble visualizing the entire relation, however, for he quickly moved to an inside observer perspective that allowed him to more adequately sight from the sun's position to the dowel. The inside perspective defined Malik's working space, and the various gestures Malik employed allowed him to work more efficiently. It is this movement to an inside perspective coupled with the working gestures that gave us the sense of "work in progress." Malik had achieved a
physical relation with his model that allowed him to begin predicting more precisely.

Malik: cause usually when if you go outside ke believe this is outside
gest: [stoops slightly, right hand gestures toward floor in front of him]
gestcode: deictic, content-carrying
persp: outside observer

Malik: if the sun is: di-<directly> [with "overhead" implied by eye gaze]
gest: [looks up above head on "sun"] [left loose hand bounces on "sun"
then stops up next to his head on lengthened "is"] [beat on "di-"]
eye gaze: eyes up
gestcode: beat, speech-timed
verbcode: verbal hesitation, interrupts self
persp: inside observer

Malik: xxx <part> xx it would be (1 sec)
gestl: [right hand beat on "<part>" toward floor and dowel] 2 [moves sun
hand to behind head]
gestcode 1: beat, speech-timed
verbcode2: hesitation
persp2: inside observer

Malik: uhm
gest: [sights from hand to dowel]
eye gaze: sighting
verbcode: filled pause
expl: relating two elements in model (gest)
persp: inside observer

Malik: <There'd be> xxx
gest: [right hand starts tracing line from sun hand to stick, body continues
along trajectory toward stick, left hand stops being the sun and starts
to point at stick before interruption from teacher]12
gestcode: deictic, tracing, content-carrying
expl: begins prediction (verb), relating two elements (gest)
persp: inside observer

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12Note that this is a complex gesture that involves body movement, manual tracing with one hand, and a shift
from iconic to a point in the left hand.
---------------------------------------------------

Malik became more internally oriented as he worked through his prediction,
ultimately speaking so softly (where the transcript breaks off prior to these comments)
that he was unintelligible on the videotape, prompting the teacher running the camerato
ask him to remember that he had an audience. Throughout this private prediction process,
Malik assumed an inside observer perspective. As Malik shifted to an outside
perspective, in the continuation of the transcript (shown next), he more precisely
expressed himself verbally, talking about the "sun's rays" rather than "it" and revealing
the conceptual tool that helped him to predict. This tool was a triangle, created by the line
of the sun's rays as they hit the top of the stick and extended to a point of intersection
with the floor. Malik used this point to mark the length of his predicted shadow, given a
particular height of the sun. Before he continued with his prediction, however, he
returned to the inside perspective, tracing, and finally using his entire arm in participant
perspective to represent the hypotenuse of the triangle formed by the shadow and stick.
The bulk of the predictive work was carried by gestures occurring during silence.
Teacher2: talk to the camera

Malik: the rays are gonna be ...
gest: [looks at camera]
verbcode: lexically specifies prior gesture
eye gaze: eyes toward audience
persp: outside observer

Malik: (silent)
gest: [kneels down close behind a stick]

Malik: hitting off the top,
gest: [index points to top of stick, touches on "top" with extended arm]
gestcode: deictic, redundant, speech-timed
expl: predicts where rays will hit stick (verbally and gesturally)
persp: outside observer

Child: xxx (unintelligible)

Malik: which will make,
gest: [leans into gesture space, placing hand at point on previously established line from sun to stick above the stick, drums fingers in air on "make"]
gestcode: beat, speech-timed
expl: begins prediction (verb)
persp: inside observer

Malik: (silent 1 sec)
gest: [traces line from spot above to spot on floor, fingers spread]
gestcode: tracing gesture, content-carrying
expl: predicts shadow length (gesturally)
persp: inside observer

Malik: the shadow, length about right here.
gest: [retraces the line, this time with more fully formed hand shape, fingers together and touches floor on "here"; when they touch the floor his arm is still touching the top of the stick, forming a hypotenuse].
gestcode: retracing gesture, enhancing
expl: verifying gestural prediction of shadow length
persp: participant perspective

After successfully predicting one shadow length, Malik seemed aware that his evidence thus far was insufficient. He could not plausibly argue for differing shadow lengths in the streetlight example with one shadow alone. He therefore manipulated the height of the sun, first lowering it to create a longer shadow, then raising it for a shorter one. He continued to observe his actions from the inside, making the relevant predictions, but omitting the tracing gestures that earlier marked his predictions. Any such omission was significant, for it suggested that Malik no longer needed to trace as he conceptualized how shadows lengthen and shrink with change in the sun's height.

Malik: But if the sun was over here,
gest: [moves sun hand behind himself, lower than first placement of sun]
gestcode: deictic, enhancing (a point lower than the first)
expl: runs a model to generate new data
persp: inside observer

Malik: the shadow will be longer

gest: [traces nearly horizontal line starting from stick and extending away]
gestcode: tracing, enhancing
expl: predicting
persp: inside observer

Malik: If it's right here

gest: [hand higher and behind]
gestcode: deictic, content-carrying
persp: inside observer

Malik: it'll be shorter.

gest: [lets sun hand drop to resting on "shorter"]
gestcode: gest pause
expl: predicting

Malik: If it's high--

gest: [raises sun hand even higher, then lets it drop to resting]
gestcode: deictic, redundant
persp: inside observer

Malik interrupted his model running to conclude with a generalization, creating a continuum of sun heights linked to growing or shrinking shadow lengths, all dependent on the angle with which the sun's rays strike an object. His discourse became more narrative, which his gestures reflected by assuming more iconic qualities.

Malik: the higher the sun is to this,

gest1: [starts low, raises hand on "sun"]
gest2: [right hand touches top of stick on "this"]
gestcode 1: iconic, redundant
gestcode2: deictic, content-carrying
expl: begins generalization (verbal)
persp: inside observer

Malik: the shorter it'll be,

gest: [continues to touch top of stick while relaxing sun (left) hand]
gestcode: mismatch {shadow will be short (verbal), not stick (gestural)}
expl: completes generalization
persp: outside observer

Malik: if it's down low here,

gest: [places left sun hand low behind him]
gestcode: iconic, redundant
persp: inside observer

Malik: this will be longer.

gest: [taps top of stick on "longer" and relaxes sun (left) hand]
gestcode: mismatch (shadow not stick will be longer)
expl: prediction
persp: outside observer
Malik: (silent)
gest: [Goes back to his place]

In this summary, Malik introduced two gestural-verbal mismatches that could potentially have confused his audience. On the surface, he appeared to be saying that the stick, not the shadow, would be longer. Coming as they did at the end of his discourse, however, the force of his earlier argument might have helped the audience to assume he meant "shadow." Tapping the stick might furthermore have been construed as a general reference to the "triangle tool" used to generate shadow lengths. We do know that his summary went unquestioned by the teacher, which provided an indirect measure of clarity, though the impact of his argument on other members of his class is not known, because Malik's performance was followed by another presentation rather than general discussion.

**SUMMARY AND CONCLUSION**

This article began by asking whether gesture might distinguish between two language activities-explanation and description-that commonly associate with distinct ways of knowing and doing science-sense making and transferring knowledge, respectively. The coding scheme applied here demonstrates that specific gestures do associate differently with explaining and describing. In what follows, we (a) review how gestures and perspective taking distinguish the two, (b) address why the distinction exists, (c) discuss the scope of the work performed by gestures in science talk, and (d) posit implications for the classroom.

**Gestures and Perspective Taking Distinguish Description From In-the-Moment Explanation**

Gestures used to describe models are typically timed with speech. Redundant iconic gestures and simple points emphasize the spoken meaning, adding little new information. The speaker signals concern with an audience by looking in its direction, not at his or her hands. By remaining physically outside the gesture space, shifting infrequently between perspectives, the speaker communicates that he or she views his or her subject matter from a distance.

Gestures used to explain in-the-moment more frequently precede related verbal content-they foreshadow speech. We saw, in contrast, that students who describe models or previously thought-out ideas tend to time gestures with stressed words or allow gestures to linger beyond words, as was the case with Quinton. Such gestural foreshadowing, characteristic of interwoven gesture talk, provides a remedy for the communicative shortcomings of gesture-carried talk. It does so by verbally specifying an idea after it has been expressed gesturally. Rather than being preplanned, allowing for gestural-verbal synchronism, the communication assumes the status of "planning in progress." While explaining in-the-moment, speakers often gesture iconically to enhance meaning and elaborate their points and beats to assist with predicting from and relating elements in a spatial model.

Forms of perspective taking, too, associate differently with explanation and description. Gesture stance and eye gaze combine to define a speaker's perspective and the role of his or her talk, whether it be describing, explaining, or some other role not addressed here. Participant perspective was not naturally abundant in the data collected from these sixth-grade science lessons. When it occurred, teachers usually created a task requiring pantomime, such as the one Jake's teachers presented him with. Jake assumed the participant perspective, as he spoke about scientific content, but maintained eye gaze with his audience. Using this perspective, he illustrated rather than experimented, failing
to actively coordinate the position of sun and earth for various seasons.

The students who manually gestured as they described science ideas gestured in front of their own bodies, maintaining physical distance between themselves and their hand motions. For example, throughout Erma's assertion that there are only two seasons at once, she remained outside the gesture space, motioning in front of herself and referring to the globe as an outside prop. From other observations of this sort, we suspect that such physical distancing provides an essential clue regarding the speaker's orientation toward his or her speech task. When students place themselves outside the gesture space, and remain there, they have typically been describing rote-learned or pre-thought-out ideas to another person, either a teacher or classmate.

A different pattern emerges when students explain in-the-moment. Students step into their gesture space, establishing a more intimate relationship with their discourse than is seen when students remain outside observers. At the same time, however, they retain a measure of objectivity that is lacking in the participant perspective. We have seen that Malik used the closeness with his model to help himself visualize the relations between sun, top-of-stick, and shadow length. The working space provided by an inside perspective allowed him to more efficiently watch his gestures, establish relations between parts of a model, predict outcomes, and verify those predictions. Malik did not become his model, however.

The concept of perspective raises the question, "What status do objects have in students' science discourse?" When students talk about seasons and refer to the globe, is this object serving as a demonstration device, providing concrete reference for ideas? Or does it become integrated more fully into the speech action, serving as a tool for uncovering relations, predicting, generalizing, and running models? The perspective of outside observer seems to assume the former object status. All references to the object are external to the gesture space, whereas eye gaze is audience directed, supporting its status as a demonstration device.

This research only begins the exploration of how perspective taking functions in science discourse. My data, restricted as it is to the discourse of 11- and 12-year-olds provides only a slice of the picture. Clement and Barowy (1993), in their work with physicists and college physics students, noted similar shifts in perspective. The movements they described are more subtle than the ones noted here. For example, as their participants solved physics problems out loud, they often brought their gesture space in closer to their body and were less bold in gesture production, as if the gestures had assumed a private rather than a public function. Malik also became more private, but in the verbal rather than the gesture channel.

The results reported here extend Cassell and McNeill's (1991) assertion that gestures provide a window into discourse structure. In addition to signaling changes among different narrative levels in a single language activity (such as storytelling and problem solving), gestures also play a role in distinguishing between distinct language activities—in this case narrative description and in-the-moment explanation.

That gestures distinguish explaining from describing lends explanatory power to the theory of sense making. In earlier work, Newman et al. (1992) told how running a model to perform work differs from describing a model as the correct answer—namely that the former is grounded in empirical evidence that the latter lacks. When a student describes a model as a right answer, he or she may use all of the necessary causal language, creating the impression that an explanatory mechanism is present. This student can sound quite scientific as he or she describes a scientifically accepted model. But when a speaker describes a model, that description carries a different epistemological force than had he or she explained by running the model. When running a model, the speaker represents events on a deeper, connected level—the elements are dynamically interconnected into a working system that allows one to predict or revise. In revising actively run models, the speaker draws on his or her knowledge of the relation among elements. Revisions follow as logical extensions, not simply as attempts to remember a memorized depiction of a
model ("I don't remember which way it spins").

Might Gestures Promote Mental Imagery in Problem Solving?

We might ask why gesture differs for the two language activities. What benefit to learning might accrue? Running models as one explains implies an in-the-moment relation with a model that can be manipulated, tinkered with, refined, tested, revised, or scrapped. The gestures described here appear to help fifth and sixth graders "actively reason-in-the-moment" (I. L. Lemke, personal communication, March 15, 1993) as they run models. Gestures fix two parts of a model in space, help students interrelate components and mechanisms, and quite possibly become internalized as mental imagery. Gestures, then, might do the work of leading the thinker toward a new level of understanding and new ways of problem solving. It is premature to speculate whether gestures can change thinking. But the fact that students revised their predictions after realigning their gestures suggests that language and gesture work together as students formulate explanations and check accuracy.

A Vitae for Gestures at Work

What scope of work do gestures perform in science discourse? The work accomplished ranges from marking the point in the discourse that a specific act of reasoning-in-the-moment begins, to establishing relations among the elements in a model, adjusting and revising a model, and predicting. Retracing gestures, which often cluster with verbal hesitations and downward eye gaze, seem to signal those moments of active reasoning. Sighting and tracing of pathways often accompany predictions from the model, whereas resolving points seem to reflect a process of verifying, or becoming more certain, of that prediction.

Describing does have a place in the discourse of science, even though it is not as closely associated with what we think of as the real work to be done, that of connecting data with models and actively running those models, predicting and revising in the process. To adequately set the context for reported research, experimental method must be described. Descriptions of method carry many of the features of narrative-introduction and description of subjects (characters), temporal organization, and attention to descriptive detail. Such detail allows readers to decide if conclusions are to be believed in light of methods and enables the important validity check-replication-to take place.

Modifying the diagram in Figure 1 that distinguishes transmitting knowledge from sense making, we can add more detail regarding the level of preplanning involved and the associated language activity. A continuum such as the following may be superimposed on Figure 5 to show relative degree of planning required for describing facts, methods, and prior knowledge (preplanned), and explaining to self (planning in the moment).

Implications -- A Model of Classroom Learning and Future Research

We may view Figure 5 as a model of the range of possibilities for science talk in a classroom. Teachers often speak from the left-hand side. Their preplanned lectures transmit information, modeling little of the self-explanation and model running so crucial to engagement in science. Student presentations also fall into the sphere of transmitting knowledge. At the other end of the spectrum, connections are made in-the-moment while explaining to oneself. Students need opportunities to explore, experiment, and run their models-opportunities often provided in small-group work. Given planning time, their initially inarticulate self-explanations can be clarified in the process of explaining to others.
The overlapping region between transmitting knowledge and sense making, describing and explaining, provides an intriguing space for further study. The person entering this space, whether student or teacher, strikes a pedagogically useful balance between planning in-the-moment and rote lecturing. Explaining to others might best happen here. The speaker or "explainer-to-others" leads the listener in a preplanned direction while remaining sensitive to his or her questions, conjectures, and prior knowledge. This space mirrors in function the perspective we have termed inside observer, for some distance from the explained model is maintained while retaining the option to revise, model, and explain to oneself anew.

This research, as summarized, emanated from classroom discourse about spatial science concepts. Generalizability to other science and math content is a subject for future research. Possibly some of the gestures identified here, such as tracing points, help students represent spatially but would be less useful for nonspatial subject matter. However, evidence of the cross-content importance of gesture in science explanation exists in the literature. Clement and Barowy (1980, 1993) noted that kinesthetic pushes and pulls accompanied efforts to explain forces. Thus gesture accompanies efforts to explain imagined forces as well as spatial relations. Roschelle (1992) found that iconic gestures and tracing points to a computer screen did more than clarify ambiguous and indecipherable speech. His two young participants interacted through conversation and gesture to converge toward conceptual understanding of acceleration.

The concept of perspective may turn out to be as useful in examining explanations of scientific models as it is in describing narratives. We have noted here a tendency for model describers to prefer a perspective that places them outside the model as an outside observer. In contrast, students who are actively explaining models often step within the gesture space, usually as inside observers who still sight and trace in their role as problem solvers.
solver rather than assuming the role of participant in the model. All three areas, generalizability to other math and science content, the role of gesture perspective taking, and implications for pedagogy represent fruitful next steps for research.

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