The Role of Gesture in Instructional Communication: Evidence from an Early Algebra Lesson

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Abstract: Little is known about how teachers vary their communicative behavior in order to scaffold students' understanding in naturalistic instructional settings. We examined a teacher's instructional discourse and gesture use during a sixth-grade mathematics lesson that focused on algebraic equations. Informed by prior research in non-educational settings, we hypothesized that the teacher would regularly use gesture to "ground" her verbal utterances, and that she would exhibit more gestures for aspects of the lesson content that are more abstract. We found that the teacher frequently used gestures with instructional utterances, and that she used more gesture when discussing abstract concepts and referents. Pointing was the most frequent grounding act overall, and was often used to highlight abstract relations between referents (e.g., the pan balance and the equation). Representational gestures were next most frequent, and often served to provide a familiar ground (such as removing equal objects) for new, abstract ideas (canceling out equal variables). Gesture thus seems to serve as a form of scaffolding. It may also provide insights into teachers' expectations about difficult material as well as their beliefs about student knowledge and conceptual development.

Introduction

Under ideal circumstances, teachers scaffold students' emerging understanding of lesson content. This scaffolding may be achieved in a variety of ways, such as by adjusting lesson content or by adjusting the way in which lesson content is communicated. It seems obvious that the nature and quality of teachers' communication has consequences for students' learning. However, relatively little is known about how teachers vary their communicative behavior in order to scaffold student understanding in naturalistic instructional settings.

In this paper, we consider the possibility that teachers use spontaneous *gestures* along with their speech in an effort to scaffold students' understanding of lesson content. Previous research has documented that teachers do indeed use gestures in classroom settings (Neill, 1991; Neill & Carswell, 1993; Zukow-Goldring, Romo, & Duncan, 1994; Flevares & Perry, 2001). However, previous studies of teachers' gestures have not examined gesture as a form of scaffolding.

Studies conducted in non-educational settings have demonstrated that listeners do in fact glean information from speakers' gestures (see Kendon, 1994, for a review). Speakers' gestures facilitate listeners' comprehension of verbal language, particularly when the verbal message is ambiguous (Thompson & Massaro, 1986), highly complex (Graham & Heywood, 1976; McNeil, Alibali, & Evans, 2000), or degraded in some way (Riseborough, 1981, Experiment 3). Based on this prior work, it seems likely that students' comprehension of lesson content may also be aided by teachers' gestures. Gestures may be particularly important in classroom settings because students' comprehension is often challenged by instructional discourse that presents new concepts and uses unfamiliar terms.

We hypothesize that teachers use gestures to "ground" (cf. Lakoff & Nunez, 2001) their instructional language, that is, to directly link their words with sensory-motor experiences such as physical objects, actions, diagrams, or other inscriptions. This grounding may make the information conveyed in the verbal channel more accessible to students. Thus, by providing gestural grounding where appropriate, teachers may foster students' comprehension of their instructional language, and in this way, they may scaffold students' understanding of

lesson content. If teachers are sensitive to this grounding function of gesture, they should vary their use of gesture, using more gestures when greater scaffolding is needed. Thus, teachers should use gestures more frequently when they speak about concepts that are more complex.

In brief, the purpose of the present study was to investigate a teacher's use of gesture in naturalistic classroom communication, with a focus on the role of gestures in grounding verbal content. We expected that the teacher would regularly use gesture to "ground" her verbal utterances. Further, we predicted that the teacher would produce more gestures for aspects of the lesson content that are more complex.

To address these issues, we selected a sixth-grade mathematics lesson that focused on algebraic equations. This lesson was chosen for several reasons: because it provided ample opportunities for discussing abstract concepts, because the lesson content was challenging and unfamiliar for the students, and because it included a long segment in which the teacher addressed the class as a whole, for which the teacher's gestures could be examined.

Method

The school was situated in a suburban community and operated with a "middle school" philosophy. The student body was 86% Caucasian, 6% Asian, 5% Hispanic, 2% American Indian, and 1% African-American. 12% of the student body received free/reduced lunch, and 13% were in need of special education services. The mathematical performance of the students in the classroom on the California Achievement Test (CAT) ranged from the 5th to the 99th (highest) percentile. Students were algebra novices, though they had participated in an earlier set of lessons on simple algebra story problem solving about 3 months earlier. Algebra was not a standard part of the sixth-grade curriculum for this school. However, the teacher was participating in an experimental program aimed at understanding early algebra learning and instruction. The content of this lesson was not specifically developed within this research collaboration, but was chosen by the classroom teacher, based on materials she had obtained earlier.

Source of Data

The data for this study came from a video recording of a sixth-grade mathematics lesson designed to introduce students to the use of algebraic equations to model the physical world. The goal of the lesson was to support the construction of students' understanding of how algebra equations can serve as mathematical models of physical systems, and thereby help to give meaning to equations and systems of equations. The focus was on the use of illustrations of pan balance scales (Figure 1) with various combinations of objects of unknown weights. As the teacher described it (Video of 1/21/99), "We're going to translate some of these … pans into equations."

The teacher operated with several major objectives: First, she set out to show the parallel structure between the pan balance and important features of equations, particularly how balance related to equality (and to the equal sign), how collections of the same object related to scalar multiplication, how collections of different objects related to addition (and to the + operator), and how the unknown weight of each object related to the use of variables. Second, she supported students' construction of possible algebraic models of the pan balances. Third, the nature of the problems led to the construction of systems of interrelated equations that could be simplified through meaningful operations, such as canceling out equal objects from opposite sides of a pan balance (or equation), and substituting known relations (as when one sphere balances the weight of two cylinders).

The analyses focus on instruction with two pan balance configurations (problems A & B, Figure 1). Students constructed equations to symbolize the configurations of the pan balance and attempted to simplify these equations, first working individually, then in small groups. The current analyses start when the teacher convenes a whole class discussion on algebraic modeling.

Coding

The analyses are based on 14 minutes from a 90-minute class that included other mathematical and administrative activities. The video excerpt was transcribed to document all of the teacher's discourse, including her vocal utterances and hand and arm movements. There are manifold ways to unitize transcripts of naturally

occurring dialog (Atkinson & Heritage, 1984; Goodwin, 1994; Ochs, Schegloff & Thompson, 1996). We chose to use idea units like those used by Kintsch (1998), where unit boundaries occur with change of speaker, intonation and topic, or extended pauses. Each unit was an utterance that was or was not accompanied by a gestural action.

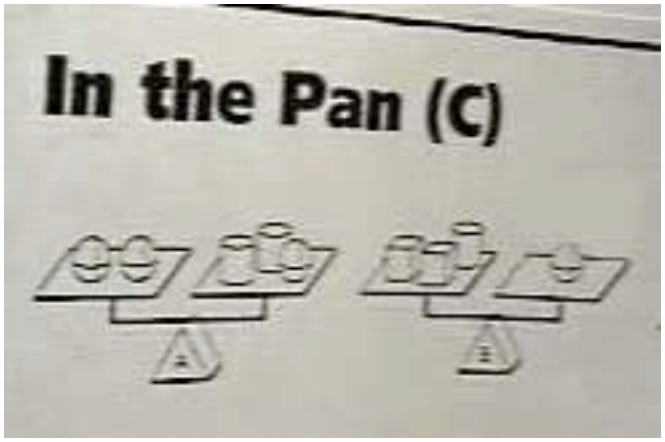

Figure 1. Pan balance problems *A* ($2S = 2C + S$) and *B* ($2B + C = S$).

Figure 2. Teacher pointing with her pen.

Figure 3. (a) and (b) Examples of representational gesture, accompanying "I'm gonna take away a sphere from each side." (a) Teacher mimes picking up a sphere from each side of the pan balance. (b) Teacher mimes picking up the variable *S* from each side of the equation. (c) Example writing gesture.

Types of Utterances

There were 195 teacher utterances coded using four categories: Speech alone (SA), speech with pointing (S+P), speech with writing (S+W), and speech with representational gesture (S+G). These gesture codes had been developed prior to analysis, based on previous research on teachers' use of speech and gestures (e.g., Alibali, Sylvan, Fujimori, & Kawanaka, 1997). Examples of each category are shown in Figures 2 and 3. Utterances could receive multiple codes.

The SA code is self-explanatory. S+P was coded when the teacher pointed to some specific place or object while speaking. For example, in Figure 2 the teacher points with her pen to the two balanced scales. (N. B. Numbers in parentheses indicate length of silence in seconds, while numbers in brackets below the transcript refers to gestures.). She states,

Teacher: "OK, um (1.9) we want to think of these <u>wedges</u> as the equal sign, right?"
{1}{2}{3} {4}

{1} Points with pen to the fulcrum of Pan A
{2} Points with pen to the fulcrum of Pan B
{3} Points with pen to the fulcrum of Pan A
{4} Writes "=" underneath the fulcrum for Pan A

S+W was coded when the teacher wrote while speaking, as with gesture 4 in the example above. As a second example, in the following excerpt the teacher wrote the equation $S = C + C$. (NB. The symbol "=" in the transcript is used when t here is no overlap between the end of one unit and the beginning of the next.)

Teacher: "I have an S (.2) is equal to="
{1} {2}
Student: =see see

{1} Writes "S" on the overhead
{2} Writes "=" next to S

S+G was coded when the teacher's speech was accompanied by a gesture used to represent some object, action, concept or relation. *Representational gesture* as used here collapses across the categories of iconic and metaphoric gesture as described by McNeill (1992). It refers to gestures that pictorially "bear a close formal relationship to the semantic content of speech" (p. 12) by referring either to a concrete object or event, or an abstract, "invisible" idea (p. 14). For example, Figure 3 shows a sequence of still frames of the teacher first (a) miming plucking (pictures of) two spheres from either side of pan balance A, then (b) "picking up" an *S* variable from both sides of an algebraic equation (note how her left hand has shifted down the screen from the pan to the

equation area), and then (c) demonstrating how to notate (with a writing gesture) subtracting equal variables from two sides of an equation. The verbal transcript for this segment is provided in the Appendix. Pointing, writing and representational gesture are all taken to be forms of grounding acts as discussed earlier.

Referents of Utterances

In addition to coding the *types* of utterances made by the teacher, utterances were coded for their *referents*. Three categories of referents were of particular interest: (1) depictions of a pan balance for a given problem; (2) written, visible equations used to model the pan balance; and (3) conceptual links or correspondences made between particular configurations of the pan balance and an equation. These three referents were, a priori, assigned a position along the concrete-abstract continuum based on their perceived level of independence from particular, real-world artifacts and generality of applicability across situations (Gainsburg, 2003). Thus, pans as illustrations of physical objects were taken to be the most concrete of the three types of referents. Equations as inscriptions were considered to be less concrete, but still physically locatable, and therefore of a moderate level of abstraction. Links are ephemeral correspondences typically made by the teacher to highlight parallels between the physical and spatial structure of the pan balance and the formal structure of associated algebraic models. Although links are not objects, inscriptions or places, like the balance or equation, they exist conceptually. Links were considered to be the most abstract of the three referents.

Results

The present analysis focuses on the teacher's use of grounding and on how grounding varies depending on the referent of the utterance.

How Many of the Teachers' Utterances are Grounded?

Overall, 61% of the teachers' utterances included some form of gestural grounding. 20% included at least one instance of pointing, 22% included at least one instance of representational gesture, and 13% included at least one instance of writing along with speech. Some utterances included more than one form of grounding.

If the analysis is restricted to utterances that focus on the instructional task itself (i.e., utterances that focused on the pan, equations or links between the two), the teacher's use of gesture is even more striking. For this subset of utterances, 77% of the teachers' utterances included some form of gestural grounding. 33% included at least one instance of pointing, 24% included at least one instance of representational gesture, and 20% included at least one instance of writing along with speech. Thus, as predicted, grounding with gesture was pervasive in the teacher's instructional communication.

How are Utterances with Different Types of Referents Grounded?

Recall that we hypothesized that the teacher would produce more gestural grounding for aspects of the lesson content that are more abstract. Based on this hypothesis, we predicted that the teacher would produce the greatest number of grounding acts for utterances about the link between the equation and the pan, and the least number of grounding acts for utterances about the pan itself. As seen in Figure 4, this exact pattern was observed.

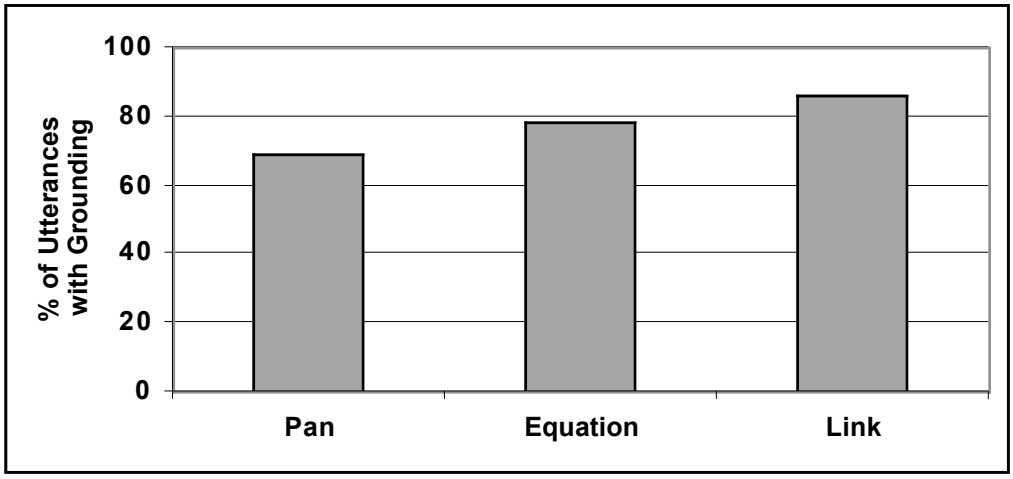

Figure 4. Proportion of utterances of each type that included some form of grounding.

Because many utterances included multiple grounding acts, we next examined the mean number of grounding acts per utterance (see the total height of the bars in Figure 5). Utterances that referred to links between the pan and the equation received the greatest number of grounding acts per utterance (M = 1.24, SE = 0.19), followed by utterances that referred to the pans (M = 0.92, SE = 0.13), followed by utterances that referred to the equations (M = 0.69, SE = 0.09), $F(2, 104) = 4.16$, $p = .02$. Post hoc tests indicated that utterances referring to links received significantly more grounding acts per utterance than utterances referring to equations. Note that, on this measure, utterances about pans received more grounding acts than utterances about equations. On the measure of percent of utterances with grounding, the reverse was true. This suggests that for utterances that are grounded, utterances about the pan were more likely than utterances about equations to receive multiple grounding acts. Indeed, only 20% of utterances about equations received multiple grounding acts, compared to 36% of utterances about pans. Strikingly, 58% of utterances about links received multiple grounding acts. This is because such utterances often involved a pointing gesture to some aspect of the equation, followed by a pointing gesture to the corresponding aspect of the pan, or vice versa.

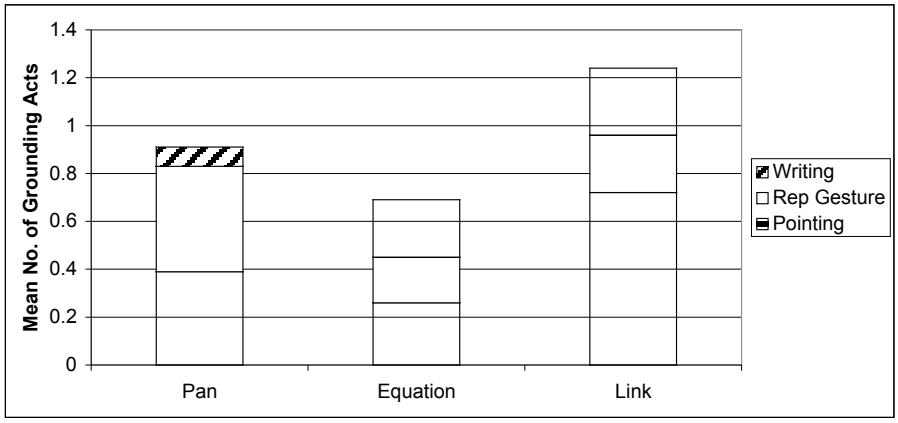

Figure 5. Mean number of grounding acts of each type produced for utterances with each referent.

Finally, we examined the mean number of each of the three types of grounding (pointing, representational gesture, writing) for each referent. The data are presented in Figure 5. As seen in the Figure, pointing was the most frequent type of grounding overall, followed by representational gesture and then writing. Pointing was especially likely to be used for utterances about the links between the pan and the equation, in part because pointing is adept at highlighting correspondences. Representational gesture was especially likely to be used for utterances about the pan, in part because actions such as removing objects from the pan often were described using gestures.

Discussion

The present results suggest that gesture is pervasive as a form of grounding in instructional communication. The more abstract the content of an utterance, the more likely that utterance was to incorporate some type of gesture. Furthermore, the types of gestures that were used depended on the referents of the utterances. As seen in Figure 5, utterances about the pan frequently incorporated representational gestures, whereas utterances about equations often incorporated writing, and utterances about links between the equations and the pans often incorporated pointing gestures. Thus, different referents afforded different types of gesture. The depiction of the pan, a physical object, afforded gestures that represented physical actions. The equation, an inscription, afforded gestures that embellished or elaborated that inscription. Conceptual links between the two were often realized in sets of pointing gestures that highlighted correspondences, or in some cases, writing gestures that delineated the correspondences with lines and arrows.

An extensive body of past research has shown that gestures made by children and adults reveal aspects of their thinking (e.g., Crowder, 1996; Crowder & Newman, 1993; Goldin-Meadow, Alibali & Church, 1993; Perry, Church & Goldin-Meadow, 1988; Schwartz and Black, 1996). Schwartz and Black (1996) have argued that spontaneous hand gestures of problem solvers are “physically instantiated mental models” (p. 464). Along the same lines, we suggest that teachers' gestures may also reveal important aspects of their thinking, both about lesson content and about students’ abilities. If teachers produce more gestures when they believe students need

greater scaffolding, then teachers' gestures may be an index of their implicit models of students' knowledge and potential areas of difficulty. Indeed, teachers may use gesture differently when explaining the same content to different students, depending on their views of students' abilities. This is a possibility we plan to explore in future work.

Several implications for teaching and for the field of Learning Sciences emerge from this research. This work examined discourse in the rich and complex setting of the classroom. The teacher often used gesture to direct students' attention, ground abstract concepts and make conceptual connections between objects and processes on the one hand and formal representations on the other. The perspective offered by this research emphasizes the communicative nature of teaching (Valenzeno et al., 2003; Neill, 1991; Neill & Carswell, 1993). Our findings underscore the importance of this often-understated aspect of teaching for teacher education and professional development. This work also acknowledges the many tasks that teachers face in communicating abstract material to students for the first time. One characteristic of gesture is that it works in tandem with speech, providing conceptual grounding for novel, abstract ideas in a visual and holistic manner. Teachers can use the verbal modality to articulate abstract concepts, while using gesture to direct students' attention to the referents of their speech, and to ground those abstract concepts to ideas that are concrete and familiar.

Additionally, this work contributes to the diversity of methodological perspectives for research on learning and teaching complex material in natural settings. Gesture research broadens the scope of discourse analysis to include bodily motions, objects and inscriptions, as well as the language used to refer to them. Most research fails to acknowledge the multimodal character of human communication (Lemke, 1998), and methods that draw exclusively from the quantitative perspective typically do not admit such forms of evidence. To capture this multimodal aspect of discourse, our approach is both qualitative—in our examination of the nature of teacher instruction and discourse—and quantitative—in our statistical analysis of frequencies and types of gestures used when discussing different foci of the lesson. Examples of an integrated approach of this sort may be useful as the field of Learning Sciences seeks to re-frame the current debate surrounding methods for educational research.

The current study sheds some light on instructional practices that are often overlooked in analyses of speech alone. However, the study has several limitations. First, the study focuses on one lesson provided by one teacher. Differences in teaching content, teaching style, and the population of students may influence how gesture is used to scaffold new mathematical concepts. The larger body of gesture research suggests that some of these patterns will likely appear across these different settings, but this must be established empirically. Second, the coding of these data should be tested for reliability with other coders. Finally, it remains to be seen if the grounding of abstract ideas through gesture aids student comprehension of the lesson and leads to enhanced learning. This important issue will be the focus of future research.

Appendix: Transcript

If I take away a sphere on each side / does this still balance like Robbie said? / Yeah, it still balances / Doesn't it? / OK! So a way that you can notate that down in your equation, down here is you can say "OK, now I am gonna take away an S" / "I am gonna take away a sphere from each side" / "instead of taking it off the pans" / "I am going to take it away from this equation" / So, I'm gonna take away an S here / which is like crossing that one off / Are you with me? / (Yeah) / and its like taking away an S over here / Follow me? / … / Just teaching you a (short pause) way to notate this / and a way to think about this / Ok, so now what happens if I take a sphere / if I have a sphere and I take one away / do I have a sphere anymore? / No. (Video of 1/21/99, 5:35-6:15)

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