Making Use of Gestures, the Leading Edge in Literacy Development

Wolff-Michael Roth, University of Victoria

Quantitative and qualitative studies of knowing and learning in science and mathematics show that gestures used in conjunction with utterances are the leading edge of cognitive development. That is, gestures express new levels of understanding before a student expresses this new understanding in words; more so, gestures express the new concepts although language still holds on to the old, incorrect concepts. Being attuned to students' gestures and recognizing when they are ready to learn from instruction is therefore an important implication for teachers of this research. It has already been demonstrated that even untutored individuals are able to distinguish phases in a student's development by attending to the relationship between the science and mathematics content expressed in gestures and that expressed in language. Furthermore, it has been shown that students are attuned to the gestures teachers use and sometimes appropriate these gestures into their own expressive repertoires, thereby accelerating the development of scientific literacy.

In this chapter, I provide several detailed cases to articulate the role of situation and gesture in the development of oral and written scientific discourse. Teachers who are sensitive to contextual and gestural clues can identify scientific content from gestures even before students are ready to articulate verbally or write about their observations and explanations. When there are discrepancies between gestures and talk teachers, students are more likely to understand new concepts and therefore their readiness for instruction. Teachers can also employ gestures in ways that assist students in developing their scientific literacy.

Chapter draft to be included in Wendy Saul (Ed.), *Communicating science: Examining the discourse.* Wolff-Michael Roth, Lansdowne Professor, Applied Cognitive Science, MacLaurin Building A548, University of Victoria, PO Box 3100 STN CSC, Victoria, BC, V8W 3N4 Canada. E-mail: mroth@uvic.ca. Tel: 1-250-721-7885. FAX: 1-250-721-7767.

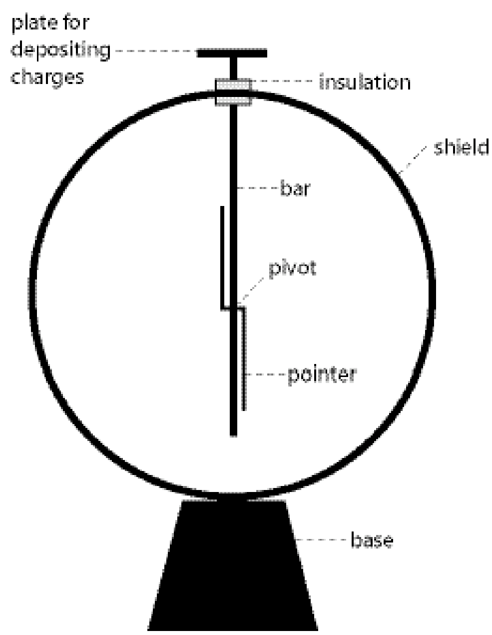


Figure 1. The electroscope that students were to explore and subsequently to explain.

From Observation to Explanation

Over the past decade, I conducted many studies in school science laboratories, closely attending to students' talk while they investigated phenomena and attempted to construct explanations for these, and what they subsequently wrote. These studies show that students often begin with "muddled talk" and end up, given a lot of time, with viable ways of talking and writing about science phenomena in observational and theoretical terms. Gestures are an important aspect because they allow students to communicate content before they are able to do this verbally, in part because gestures support the development of verbal modes by decreasing the mental effort required for producing communication. In this way, viable language emerges from what are, to the scientific ear, almost chaotic and incomprehensible utterances. Once students have developed consistent ways of verbally representing particular entities, the use of gestures decreased.

An Exemplary Episode

Phil and Marcel are two students in a tenth-grade physics class that has explored static electricity, and, in this lesson, the electroscope. This instrument consists of a vertical bar to which a pointer is attached by mans of a pivot or hinge (Figure 1). If a charged object is brought close, the pointer deflects away from the bar; if the object is removed, the pointer returns to its normal position parallel to and touching the bar. In this lesson, the students had been asked to touch the bottom of the bar while the charged object was held close to it on the opposite side and then to remove the charged object after the touching hand had already been withdrawn. Much to everyone's surprise, the pointer remained deflected. The students were asked to explore the device and its functioning to come up with an explanation of the phenomenon.

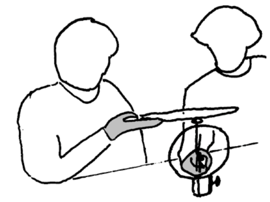
Partway through their investigation, Phil suggested, "This way it deflects," and Marcel responded, "Yes." He paused and then continued, "Now there is on top." Phil cut in by repeating what Marcel had said, "Now it is there on top," and then continued, "Now we have this problem again. This way- now I put the electrons down here again, which are drawn away up to here. I put them down here again with my finger. Then I pull it away and because now there is again an equilibrium inside, it remains like this."

If we only take the words and sentences that Phil and Marcel exchanged here and throughout the ten-week curriculum when they were recorded, we understand very little what the conversation was about. That is, if their teacher had found this "explanation" in the students' laboratory report, she would not have understood and probably would have been forced to give these students a low mark. Let us now move to consider other aspects of the interaction that I culled from the videotape. These aspects concern the objects and events in their setting, prior conversations that everyone could assume the others still remembered, and the pointing and representational (iconic) gestures students made while talking.

The following transcript, which recovers some material elements from the situation as well as the students' gestures, provide us with a much better insight to what the students' said and what their talk was about. From the viewer's perspective, Marcel sat on the right, Phil on the left. To get an impression of the hand gestures, readers may find it beneficial to scan the images one after another, paying particular attention to the position of the hands (grey).[1]

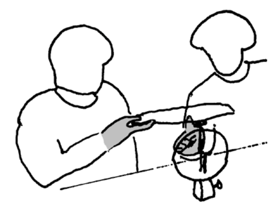
[1] * — asterisks indicates which point in the transcript corresponds to the image;
(1.27) — pause, in seconds;
[— square brackets indicate overlap of two speakers' utterances.

01 Phil: This way, it deflects *.
(*He gets the transparency and moves it above the electroscope*.)



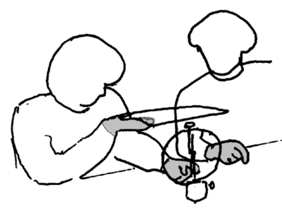
02 Marcel: Yes. (1.27) * Now it is there on [top].
(*His index finger moves up until it touches the transparency.*)

03 Phil: [Now] it is there on top, now we have this problem again.

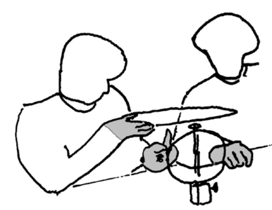


04 This way (0.43)
(*His hand, posed in his lap, comes above the table and moves toward the suspension.*)

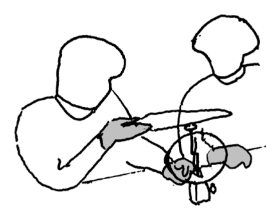
05 * now I put the electrons down here again
(*Touches the suspension.*)



06 * which are drawn away up to here. (0.20)
(*His hand turns and index finger starts pointing upward, does so for 0.36 seconds.*)

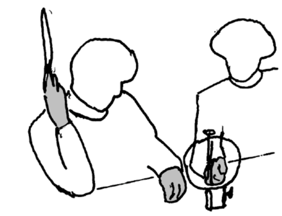


07 I now put * them down here again with my finger.
(*He moves the hand back to the electroscope and touches the bottom of the suspension with his finger*.)

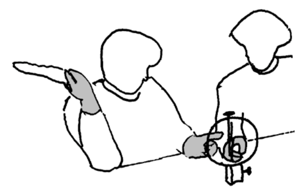


08 (1.56)

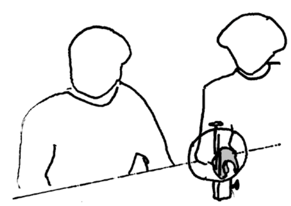
09 Then I pull it away *
(*Begins pulling the hand with transparency back.)*



10 and because (0.50) * now there is again
(*Hand moves way past his ear and stays in that position for 0.48 seconds.*)



11 * an equilibrium inside, it remains like this.
(*Both hands drop below the table top.*)



Already in line 1, we see multiple resources for making meaning provided by Phil. He said, “This way,” while bringing a charged transparency over the electroscope and added, “it deflects.” Uttering “This way” invited Marcel to attend to concurrent action, bringing the transparency film close to and above the electroscope. The second part of the utterance invited Marcel to look out for something that was appropriately described by “it deflects.” That is, the utterance invited attention to that which was brought close, a charged film, and something that deflected in response. Out of all the things in this classroom and, more specifically, on their laboratory table, Phil’s discourse picked out just a few things but without having to describe them. Furthermore, neither he nor Marcel had to mentally represent these objects because these were there ready to be picked from the environment whenever needed. In addition, the students did not even have to name the object, but using an indexical term (“this,” “it,” “there”) or a pointing gesture, oriented the other. These words, because they are so common in language, need much less mental energy and resources to be uttered than less frequent words; pointing, because it is a sensorimotor action, takes even less mental resources. What is required for sense making is available perceptually and the listener can pick up the perceptual gestalt by watching whereto the finger (or hand or gaze) is pointing.

Already in the first utterance, Phil expressed so much without actually putting everything in word that he communicated. He did not say that it was the transparency that was brought close or even that it was charged—at that point in their course, students did not even have to charge the transparency in order for others to understand that the speaker meant a charged one. In the course of this unit, the transparency had come to be used metonymically for the process of charging an object and holding a charged object. The statement is even more complex than it appears on first sight, for it actually incorporated an observation categorical, that is, pertaining to many cases. The categorical was in the form of a statement of a correlation: "Whenever you bring the charged film close to the electroscope, it deflects." It is crucial for teachers and researchers to realize that at this point, Phil was not yet at the point where he could make the abstract verbal statement on his own, apart from the situation, and without the resources that the materials and pointing provided.

As we move through the transcript, we notice that Phil communicated much more than his words did when taken on their own. His gestures and the materials present, together with his words, constituted a story line that told his listener how he understood the phenomenon. When you touch the center bar, electrons are supplied, which are subsequently drawn upward in the bar to create a charge equilibrium. The order of events was not yet scientifically correct: a charge equilibrium is created while the transparency is close as additional electrons are supplied through the hand from the electrical ground. The equilibrium is indicated by the fact that the pointer moves into its zero position. However, when the transparency is moved away, the charges re-equilibrate in the bar but there is now a surplus of electrons such that the pointer is deflected again.

During the next lesson, the two continued to work on constructing their explanation. In the course of attempting to explain the phenomenon, the needed to draw decreasingly on the materials and drew increasingly on language to express themselves. When they used gestures, it was done without the materials present and in a relatively abstract manner, whereby a gesture metonymically stood for an entire process. That is, the "story line" consisted of increasingly context independent elements.

Over the past thirteen years, I have analyzed nearly 500 hours of videotapes in science classes from fourth-grade to university level and I have studied scientists in the process of doing research for the past four years. It turns out that independent of the age, individuals draw a lot on gesture, especially when they work in the laboratory context and when they attempt to explain things that they are not yet very familiar with. There are a number of quantitative and qualitative research studies that show how students use gestures in communicating correct science and mathematics content before they can do so verbally (see my review of the literature in Roth, 2002). In fact, when there are conceptual discrepancies between gestures (correct) and language (incorrect), this is an indication that students are ready for instruction; in other words, instruction will have greater impact on these students than on those whose gestures and words are consistent but incorrect. This research also shows that teachers and other individuals, even without being tutored, can detect such inconsistencies. As students' language develops, one can notice a temporal shift between gestures, which lead, and words, which follow. The gap, which may initially range from 2.0 to 3.5 seconds, decreases to a range from 0.8 to 1.5 seconds, and eventually disappears; parallel with these temporal changes, students increasingly rely on words to communicate (Roth & Lawless, 2002b).

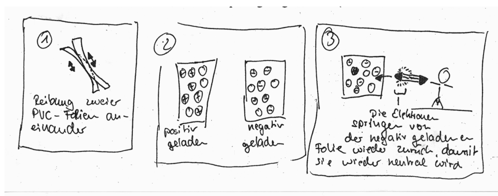
From Talking to Writing Science

In the previous episode, Phil and Matt learned to talk in the presence of materials. However, to examine what they knew, their teacher used tests in the same way that teachers around the world use tests. We might ask whether a student who is able to talk about a phenomenon is already in a position to write about the same phenomenon.

A fact that has not yet been appreciated sufficiently is that talking and writing are very different processes and pose quite different cognitive demands; writing, as Walter Ong (1988) said, restructures consciousness. Science and literacy educators ought not overlook the complexity of the change over from spoken to written language. My work from elementary to high-school science shows that this transition is facilitated when students are provided with opportunities to express themselves on paper but by utilizing means of expression that bear iconic relations with the situations they experienced and gestures that they used. In these situations, the benefits student accrued by talking in situation, surrounded by the material objects and events that they referred to and modeled with gestures, can be amplified (Roth & Lawless, 2002a). In fact, engaging students in discussions over and about diagrams that represent the phenomena they are to theorize provides an important step from doing science to writing science (Roth, 1996).

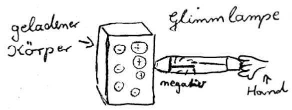
On the test where the students from the tenth-grade physics class were asked to describe and explain basic concepts of static electricity, they used drawings of various levels of abstraction from the lived experience in the laboratory. They used pictorial means particularly on the test item where they are asked to describe (and explain) how one can prove that some material is electrically charged (Figure 2). The drawings and text in Figure 2 show various levels of abstractions of what previously had been ergotic and epistemic movements that are later represented in the form of symbolic movements (iconic and metaphoric-iconic gestures). Figure 2.a depicts all objects in a naturalistic way and iconically represents the action of touching the charged body with the neon lamp in the hand; the text is in the first person. As we move down in Figure 2, the

a.



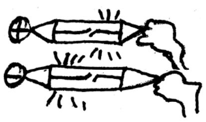
The left side of the glow lamp lights up.

b.



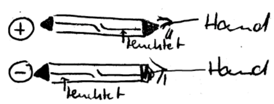
If I hold a neon lamp to a negatively charged body then that side glows which is oriented to the charged body. We know then that the body is charged negatively.

c.



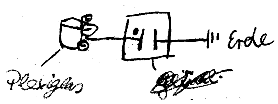
You have a charged body. You touch it, at one place, with a neon lamp. There where the film and the body touch, the body will equilibrate (becomes neutral). The neon lamp always glows on the negative place!

d.



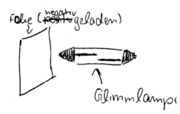
One can show that a body is charged negatively by touching it with a neon lamp. That electrode which is used to touch the body glows always then when the body is charged negatively.

e.



With a neon lamp. When I, e.g., charge a Plexiglas negatively and hold a neon lamp to it. If the Plexiglas is charged negatively, that electrode glows which is oriented towards the charged Plexiglas. The electrons flow from the Plexiglas through the neon lamp into my hand and return to ground. !!GROUNDING!!

f.



When touching that part glows which is on the side of the transparency film.

g.

«none»

You can prove it by means of the neon lamp. If you hold it to a charged body, and it is charged negatively, then that part [electrode] glows which is close to the charged body. The lamp indicates the direction in which the electrons flow.

Figure 2. A variety of responses to the test question, “How can you prove that an object is charged negatively?” The answers exemplify different stages of abstractness, from low (a, b), to intermediate (c, d), and high (e, f, and g), which is associated with an increasing independent from the situation and processes of the original investigation.

material object, its charges, the hand, and the neon lamp are represented in an increasingly abstract way. For example, in Figure 2.c, the student used simple plus and minus signs in circles to stand for the charged bodies, but shows an iconic depiction of the hand holding the bulb. In Figure 2.d, the hand is replaced by the word “hand.” In Figure 2.e., the person holding the lamp is no longer present. The last two examples abstract from the experimenter (does not appear in drawing, no drawing) and simply represent in words the action and results.

Interestingly enough, the young females had a greater preference (11 of 12) for using drawings then their male counterparts (4 of 7).

How can these results be explained and understood? Discourse is what refers to the world, *a* world shared by the interlocutors. The situation surrounds the interlocutors and can be referred to by pointing (to the bottom of the electroscope), making a gesture (moving the hand up), or designating something in an ostensive manner by discourse ("it deflects"). That is, oral discourse is ostensive. In written text, however, that which is referred to also has to be evoked. That is, the things that students point to, highlight by means of a gesture, or designate by means of ostensive discourse needs to be included in the text. This, however, is a much more complex process than speaking about things, events, and the world present at hand. Think of it this way. In a lived situation, humans make use not just of one communicative medium, language, but of three mediums concurrently: language, gesture, and the semiotic resources in the perceptual environment.

Writing introduces more than merely fixing speech. In writing, the text is rendered autonomous with respect to the intentions of the author: writer and reader no longer share a common situation and the concrete act of pointing is no longer available as a means of communication. That is, the written text transcends the psychosocial conditions of its production. It thereby opens itself to unlimited series of readings (Ricœur, 1991). The writer therefore has to supply additional resources so that the reader can recontextualize it in an appropriate way. Good scientific writing provides resources that limit the number of readings (Bastide, 1990); this requires additional work. Whether this work has been accomplished sometimes comes up in teacher-student debates, when a student claims to have provided sufficient answer but the teacher notes that the point of contention does not appear on paper.

Implications

As someone who continues to teach science in school, this research on gestures and transitions into writing science has provided me with many pointers about what to do in order to facilitate students' development of scientific literacy. I have increasingly created opportunities for students to talk in the presence of the materials; most importantly, I have asked them to *describe* and *explain* the relevant phenomena. While students attempt to describe what they have seen, they invariably, in the absence of words, use gestures to express themselves. These gestures bear great resemblance with the earlier sensorimotor actions employed for doing and sensing things in the hands-on activities that they conducted earlier. Using gestures, students already communicate even before they have the correct science words and, in the process, construct an understanding. It is from the attempt of expressing themselves that understanding evolves rather than the other way around. In the next step, when asked to explain, my students will draw on the very same gestures to articulate their first explanations, which they subsequently develop because I encourage them to do so. The more opportunities for expressing themselves you provide students with, the more their scientific literacy skills will develop. I found that with every attempt of describing and explaining phenomena, the time for doing so decreases and the number of science words increases (Roth & Welzel, 2001). Before having students write, I found it useful to engage them in whole-class conversations, where I encourage students to use diagrams on the chalkboard. Again, the presence of communicative modes other than language facilitates interactions and contributes to the development of the competency to talk science but now having scientific representations (drawings, diagrams) as an integral part (Roth, 1996). In this change, a first step toward written scientific literacy is being made, and a bridgehead exists toward even more formal, written expressions to develop.

Another important strategy for fostering the development of scientific literacy is to listen attentively to and observe students while they attempt to communicate. You may find this difficult initially, because students' talk is often very muddled in the beginning. But it is worthwhile allowing students to construct descriptions and explanations on their own because you have ample opportunities to notice any discrepancy between gestures and words. If you do notice that words and gesture are consistent but incorrect, you may better provide additional time to the student for becoming familiar with the phenomena—he or she is probably not ready yet for further instruction and development. On the other hand, when you notice a discrepancy on the concepts communicated gesturally and verbally, you can push the students, for example, by posing questions that challenge the student to elaborate even further and, eventually, to arrive at the desired level of science literacy. Similarly, if you see delays between gestures and the corresponding words, you can be sure that the student has not yet developed the desired concepts and you may provide for additional opportunities to communicate orally before the student expresses him- or herself in scientifically correct terms. It is only after students have developed competent ways of talking science that I would move to the next step of communicating in written form, at first encouraging lots of drawings and then, increasingly, using words, sentences, and paragraphs. With students up to seventh grade, I have students at that stage work on glossaries, which always include diagrams in tandem with a sentence or two.

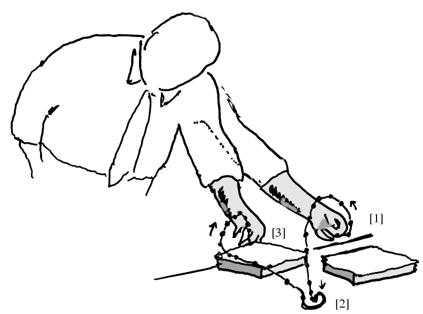
Gestures in Teaching

In the course of their lessons, teachers find themselves in different modes of teaching, including lecturing and interacting with small groups. Because these modes constitute forms of communication, aspects of the setting, how teachers are oriented toward focal artifacts, and teachers' gestures play an important role. In lectures, gestures can both help (Roth & Lawless, 2002c) and hinder students' sense making (Roth & Bowen, 1999) and therefore, their development of science literacy. I present two examples to highlight the role of teacher gestures and body orientation in small-group interactions and lectures, respectively.

Teacher Gestures in Small-Group Interactions

The following example is from the same unit on static electricity in a tenth-grade physics class. The two teachers present walked around the classroom, engaging the six groups of four to five students in conversations. In this example, the teacher (Sam) wanted to assist the students, who apparently struggled to understand a phenomenon that they produced but could not yet explain. Two metal plates lying side by side were brought into contact. A charged object was then brought close to one of the plates; the other plate was pulled away. When the plates were touched with a glow lamp, it lit up close to the hand holding it in one case but on the opposite side in the other case. In his explanation, Sam not only talked but also, and even more importantly, used gestures. His gestures metaphorically enacted the different movement of electric charges from and to the two plates, respectively.

S: Here [1] they have to leave like this [2] there they must go like this [3]. (*The teacher's hand moves from the first metal plate to the table top, then from there to the second metal plate.*)



We notice that Sam's "explanation" made use of many indexical, context-dependent terms ("here," "they," "like this," "there"). How "here," "they," "leave like this," and "there" have to be heard must be taken from the situation. "Here" and "there" are distinguished by the different positions that the same hand was taking in the course of the utterance; the two terms actively distinguished two situations without actually describing the differences in words. "Here" and "there" became significant in the context of the different observations made just prior. "They" referred to something not available in the transcript, but referred to the charges that the entire unit was about. Again, using the term "they" simplified the verbal part of the communication, which was important at this early stage in the development of student literacy concerning the phenomenon. Finally, readers will note that the same utterance “like this” was used in the two parts of the utterance, but actually referred to different things. In the first instance, electrons “leave like this,” which was accompanied by the hand’s movement from the metal plate ([1]) to the table ([2]), representing ground. In the second case, “go like this” was associated with the hand movement from the table (ground) to the other metal plate ([3]). That is, the hands metaphorically enact the motion of the electrons in the model presented by the teacher from the first plate to the electrical ground, and from the electrical ground to the second plate.

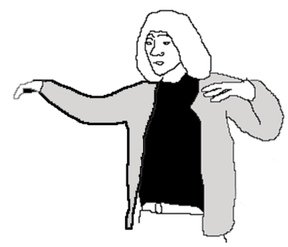
Two issues are to be noted. First, the different situations were characterized by different metaphorical gestures, one involving a movement from metal plate to ground, the other from ground to metal plate. Second, a potential danger in this gesture is the fact that students may associate the hand movement with the actual movement of electrons. According to the physicists, however, the electrons that arrive on the plate, for example, have not come from the ground, but have been bumped onto the plate by others that entered the experimenter’s body (e.g., his or her feet). That is, the gesture harbors the danger of a misconception making students think of electrons moving all the way from ground to plate when it is more like a train of electrons whereby the place left by the first ones is filled by those being a little further away and so forth until the places vacated by the last in the train are replaced from the ground.

Just as it is easier to produce sentences that contain a smaller number of low frequency words, it is easier to comprehend sentences that use a smaller number of low frequency words. In a situation where objects and events are present to hand and where students actually perceive them in the correct way (something that has to be ascertained beforehand), the teacher can rely on the perceptual ground and his or her gestures to provide additional information that students do not need to process verbally. Another important aspect of gestures in interactions is that they are seemingly “picked up” by others who use, often without being aware of it, the same or similar gesture to talk about the same topic. In this unit, many gestures that originated with the teachers or one student were subsequently being used by other students even though they were often not aware of having “picked up” these gestures from others. It is therefore important that teachers consider reflect on the gestures that they use while talking science.

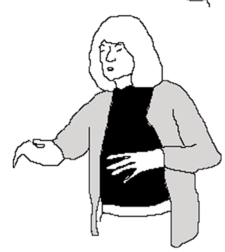
Teacher Gestures in Lectures

Gestures can be used to point out some entity in a photograph, drawing, diagram, or graph that teachers generate or project on chalkboard or screen. Gestures can also be used to depict a phenomenon in an iconic way. Both forms of gestures can facilitate students in appropriately placing words with respect to scientific representations. In the following example, the teachers of a seventh-grade science class, currently involved in the study of a local stream, Henderson Creek, had invited a scientist and environmental activist (Meg) to speak about her work. As Meg began to locate Henderson Creek on the aerial photograph projected against he screen in front of the classroom, she explained that she was working not simply to improve the health of the creek but the health of the watershed that she was highlighting with a little hand waving. She then asked students whether they knew the term "watershed," and, when there was little response from the students, began to explain.

01 Meg: So this is basically a- a * drainage area that is collecting the water
(*Her arms make several slight 'pumping gestures.*)

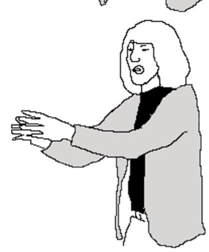


02 that falls on- * on the lands
(*Elbows and forearms descend.*)

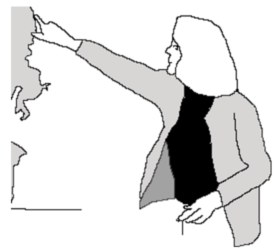


03 and it is all *
(*Steps forward and the hands come together.*)

04 funneling * down through the stream
(*Hands and arms move forward, hands enact meandering. Forward movement comes to a stop when the arms are fully stretched.*)



05 and ultimately * into Saanich Inlet.
(*Steps forward and turns toward map to point to the spot where Henderson Creek sheds into the inlet.*)



In this expert, Meg provided two forms of assistance for the construction of meaning from her presentation. First, she turned away from the projected aerial photograph and turned her body toward the students and then, second, used her arms to gesture water as it flows from the higher to lower points of the land, is funneled into the stream and ultimately shed into the inlet on which the community is located. Turning away from the aerial photograph clearly indicated that the content of her utterances was no longer perceptually available in the photograph; she moved into a narrative mode where her gestures no longer highlighted elements perceptually available but go with the content of the narrative (Roth & Lawless, 2002c). That is, this movement is a resource for interpreting in which way the gestures have to be understood. The gestures themselves provided perceptual clues for interpreting what Meg might have meant by saying "watershed" and "drainage area." As she completed her explanation, Meg turned back toward the map and, just before uttering where all the water that falls on the land and is funneled into the stream, pointed to the place where the creek empties into the inlet. Turning the body, she highlighted that now her gestures had to be understood differently, directly pertaining to entities perceptually available.

Gestures and the associated body movement allow teachers to communicate more than they say with their words. When they work in concert, the gestures and other movements provide resources that allowed the listening students to make sense of otherwise more abstract talk. The gestures and other movements literally provide a body to the talk. But gestures can also interfere with comprehension. In one study, I was able to link the difficulties of undergraduate ecology students to understand a lecture topic to temporal and conceptual shifts between gestures and the associated words (Roth & Bowen, 1999). Even mathematics education professors and graduate students could not understand what the ecology professor had said because, as I suggest, his gesture tuned listeners to the average height of a curve whereas his talk was about the average width—the concepts expressed in the two different communication modes were different. Sometimes gestures and corresponding words were shifted, the words following the associated gestures. Here, too, the listeners found it difficult to follow and had "a hard time understanding what the professor was talking about." They miss an important part of what was communicated or contributed to frame the words and therefore provide them with a specific sense.

This is important to remember when reflecting on note taking. Many teachers have heard students say that when they listened, it all made sense, but when they tried to study or recall the material during a test, they could not put it together. My work on gestures and teacher's body positioning suggests that teachers communicate more than they say—body position and gestures provide resources for making sense. Students who copy into their notebooks merely what the teacher says will miss all the gestures and shifts in body position that allowed students to make sense of the talk in the situation.

Implications

There are important implications for teachers from these examples. On the one hand, our students use the same gestures that we earlier used while talking science (most often unconsciously) to make sense of our talk. Sometimes, especially from small-group interactions, students "pick up" such gestures and employ them in their own communication efforts. At other times, especially in lectures, the gestures allow students to become attuned to relevant aspects on the chalkboard or in a science demonstration. On the other hand, these gestures never make it into notebooks when students' copy from the chalkboard or when they summarize what they have learned in a lesson. When they subsequently study for a test or exam, these gestures are absent and students find it difficult and sometimes impossible to reconstruct what was intelligible and comprehensible when the teacher talked about it. Providing students with opportunities to talk science all the while attending a lecture may help bridge the gap between lecture and lecture notes. For example, together with colleagues in the University of Victoria physics department, we developed a set of manipulatives and printed materials that lecturers in introductory classes could use to get their students to talk about the lecture content. In this way, students could engage and participate in talking physics, which included the use of gestures that supported the development of more mature physics talk before they walked away from the lecture. Often, students subsequently enhanced their notes or became better attuned to aspects of the subsequent lecture parts.

The analysis of Meg's presentation revealed that she used body positions to frame what she said and gestured. My research in other contexts indicates that some lecturers naturally engage in such framing of talk and gestures associated with conceptual differences (Roth & Tobin, 1996). From experience I now that many teachers and professors are not very expressive in their gestures and movements. Teachers may therefore think about ways in which they can use the space of their classroom and chalkboard layout so that changes in body orientation and gesture are naturally associated with different conceptual issues.

Gestures are inherently phenomenal and therefore give, through a metaphoric transformation, physical content to conceptual entities. Dangers for understanding arise because the physical image associated with the conceptual content may not be scientific. Science teachers who already know may adapt their presentations (utterances and gestures) to the requirements of the conversation so that the “essential” aspects are represented “correctly.” Thus, when Sam explained the discharging of the two plates via the glow lamp, he used gesture in which the hand moved from the first plate to the tabletop and from the table to the second metal plate. Simultaneously, he talked about “them” (electrons) that thereby move. Now, the gesture apparently indicated something that moved from the plate to the ground. Yet, physicists do not model what happens in terms of electrons that move along this trajectory. Rather, there is a current from the plate to the electrical ground but the individual electrons (to remain in that image) only move a little way along the conducting path metaphorically enacted by the gesture. Students may incorrectly interpret this as a statement that surplus electrons move all the way to the ground. That is, the teacher enacted a model in conflict with the scientifically correct one taught only a few weeks later in the same course. The particle model as enacted here, where the electrons move along a path, was incompatible with the model of current electricity.

Epilogue

There is an increasing body of literature on gesture-talk relations among native people, in industrialized workplaces, and in schools. As a collective body, the studies provide evidence that gestures are a deep feature of cognition and that they play an important role in human development and learning at all levels. Until now, science and literacy teachers have not paid much attention; further, the emphasis on writing before students can draw on the resources available from talking in situation disadvantages students and curtails their learning opportunities. It is about time that we teachers build on this other mode of communication that has such a tremendous role in the development of language and literacy. There are opportunities to be harnessed for teaching scientific literacy that go beyond what we have been using as pedagogical tools until now.

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