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Interactive Explanations: The Functional Role of Gestural and Bodily Action for
Explaining and Learning Scientific Concepts in Face-to-Face Arrangements

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Abstract

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Explaining and Learning Scientific Concepts in Face-to-Face Arrangements

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As human beings, we live *in*, live *with*, and live *through* our bodies. And because of this it is no wonder that our hands and bodies are in motion as we interact with others in our world. Hands and body move as we give directions to another, anticipate which way to turn the screwdriver, and direct our friend to come sit next to us. Gestures, indeed, fill our everyday lives. The purpose of this study is to investigate the functional role of the body in the parts of our lives where we teach and learn with another. This project is an investigation into, what I call, “interactive explanations”. I explore how the hands and body work toward the joint achievement of explanation and learning in face-to-face arrangements. The study aims to uncover how the body participates in teaching and learning in and across events as it slides between the multiple, interdependent roles of (1) a communicative entity, (2) a tool for thinking, and (3) a resource to shape interaction.

Understanding gestures functional roles as flexible and diverse better explains how the body participates in teaching and learning interactions. The study further aims to show that these roles and functions are dynamic and changeable based on the interests, goals and contingencies of participants' changing roles and aims in interactions, and within and across events. I employed the methodology of comparative microanalysis of pairs of videotaped conversations in which, first, experts in STEM fields (Science, Technology, Engineering and Mathematics) explained concepts to non-experts, and second, these non-experts re-explained the concept to other non-experts. The principle finding is that people strategically, creatively and collaboratively employ the hands and body as vital and flexible resources for the joint achievement of explanation and understanding. Findings further show that gestures used to explain complex STEM concepts travel across time with the non-expert into re-explanations of the concept. My analysis demonstrates that gestures and the body are complex, multi-functional resources that work toward cognitive, communicative, and interactional achievement and, as such, are viable resources for teaching and learning in face-to-face interaction.

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DEDICATION

For my mother, Rosemary Wealing Scopelitis

1934 - 2012

CHAPTER 1

DEPICTING THE WORLD THROUGH OUR HANDS AND OUR BODY

Introduction: Our Bodies in the World

As human beings, we live in, live with, and live through our bodies. So it is no wonder that when a person extends a finger to point towards an object, we effortlessly turn our heads to gain information on the object. It is no wonder that when giving directions we pause and wait for our recipient's head nod as a signal of being understood and cue to continue. It makes sense that when asked which way to turn the screwdriver to untighten a screw, I, use my body as a resources and rotate a fist hand clockwise in order to come up with the answer. Gestures and bodily actions, whether intended or not, are a significant part of human action. In this project I concentrate on how people use gestures and the body particularly in explanatory interactions. Studies support that in person, face-to-face explanations are typically multimodal, including quite a bit more than just talk, showing they include the body as well (Brassac, Fixmer, Mondada & Vinck, 2008; Goodwin, 1986, 2000a, 2003; Gullberg & Holmquist, 1999; Hindmarsh, & Heath, 2000, Hutchins, 2007; Hutchins & Nomura, 2011; Hutchins & Palen, 1997; Kendon, 1990; LeBaron, & Streeck, 2000; Murphy, 2003, 2005; Schegloff, 1997; Scopelitis, Mehus & Stevens, 2010; Stevens & Hall, 1998; Stevens, 1999; Stevens, 2012; Streeck, 1993, 1994, 2009). Explanations across interaction can be thought of as an intricate web involving people, things, talk, and action. Within such a complex populated web, the success of explanations in interactions becomes dependent on the capacity and synergy of participants to quickly register how and when to employ, coordinate, and attend to the many modes and resources available in order to achieve a conclusion of joint goals

(Goodwin, 1986, 2000a, 2003 Stevens & Hall, 1998). The purpose of this study is to investigate how people make use of the body as a functional resource specifically in face-to-face “interactive explanations” for teaching and learning. (I use the term “teaching and learning arrangements” to refer to social and material configurations, that people arrange for teaching and learning (Stevens, Satwicz & McCarthy, 2007).

This project is an investigation into how people make use of gestures and the body in face-to-face interaction to achieve joint understanding of STEM concepts (Science Technology, Engineering and Math) when an expert and non-expert explain to one another. I will show that participants employ the hands and body to perform multiple functions and overlapping purposes that range from communicative, cognitive and interactional activity. Integrating views of gestures as communicative acts, cognitive tools, and interactional resources, I show, that gestures and the body serve not one of these functions alone, but a collage of all of them at once in interactive explanations for teaching and learning. Identifying Gestures and the body, as dynamic and flexible participants in a multi-party, social project, that are used cross-functionally to move teaching and learning interactions toward achievement of explanation and understanding. This is a valuable extension on prior perspectives that give primary attention to one function over another. I further show that people, aware of the complex capacity of gestures and the body in interaction, creatively and strategically make use of the mutable, changeable, and flexible nature of gestural functions in interaction. How people use gestures functionally is related to the interests, goals, and contingencies of participants’ changing roles and aims within and across teaching and learning events. Understanding how people make use of gestures and the body to accomplish teaching and learning in

interaction is a crucial step closer to being able to give a useful account of what constitutes any exemplary form of effective teaching and learning. And this can, in turn, inform future designs that make use of the always-present body that we live in, with, and through.

Gesturing – “Its Just What People Do”.

During playtime at school, Izak taught Savas, my eight-year-old son, how to play a card game. That evening Savas was explaining to me how to play the same card game. The instant before he spoke, he lifted his hands in front of him with the palms facing one another, about four inches apart. It was like he was holding a small box. “You want to keep your discard pile to one side,” he said. As he spoke the words “to one side,” he slid the gestured shape to the right of his body and pushed it further into our shared interactional space. He held the shape for a moment, paused his speech, and looked into my eyes. As his gaze dropped from mine, the former gesture dissolved, clearing the space for the next one. “In your active hand,” said Savas, now lifting his left hand shoulder-level directly in front of his eyes with his palm open and facing him. He gazed for a moment at his open hand before he resumed his talk, “You have five cards.” Savas flipped his hand around, palm facing me. He pressed his hand against the air, lifting it up into my sight line as the word “five” escaped from his lips. His focus paused on me and his fanned hand held the space between us. I looked to his hand and then turned to him. I took the opportunity to offer him a nod. His hand dropped out of the space and fell to rest on his lap.

I am not at all blind to my child's gestural activity. After spending hours examining video data of the gestural practices of people in teaching and learning interactions trying to figure out what functions they are serving, I turn to my child and requested his unencumbered perspective. "Why do you use your hands like that when you are explaining to me how to play the game?" Savas sits tall. His shoulders shrug upwards.

"Mama," he blurts out in an a-matter-of fact tone, showing the slight aggravation eight-year olds have when asked a question with a seemingly obvious answer. "It's just what people do."

Savas has a point. Human beings engage their whole body when we talk. Hands wave, fingers point, heads nod. In fact, studies show that at least two-thirds of communication is accompanied by nonverbal expressions, happening via facial expressions, gestures, and posture (Bancroft, 1997). But why? What purposes do the body and its gestural activity serve in interaction, particularly teaching and learning interactions, I decided to ask Savas his opinion, "Why do you think you use your hands?" He shrugged his shoulders and responded.

"I don't know. Maybe it helps me remember what comes next."

Savas's comment is right in line with the research. Gestures do support a speaker's thought development (Arzello & Edwards 2009; Cook & Goldin-Meadow, 2006; Crowder, 1996; Goldin-Meadow, 2003, 2006; Goldin-Meadow & Church, 1993; 1999 Hostetter & Alibali, 2008; Johnson, 1987; Kelly, Barr, Church & Lynch, 1999; Kirsh, 2009; Kita, 2000, 2009; Koshmann & LeBaron, 2002; 2009; Lakoff and Nunez, 2000; Latour 2004; LeBaron & Streeck, 2000, McNeill, 1992, 1999, 2005; Patterson,

Cosgrove & O'Brien, 1980; Streeck, 2009). Savas seems to be expressing that the gestures are in support of his own thinking. It is as if he is saying, "My gestures are acting "for me".

Savas goes on. He fidgets a bit, and a smile draws across his face. He goes on. "And, well, you're not that good at games. So, I think I use my hands because it helps you know what to do so you can actually play with me." Again, my son confirms another line for the use of gestures in interaction— gesturing helps to communicate ideas to another. (Becvar, Hollan & Hutchins, 2005; Brassac, Fixmer, Mondada & Vinck, 2008; Enfield, 2009; Goodwin, 2000a, 2000b, 2002; Gullberg & Holmquist, 1999; Kendon, 1990, 2004; Knapp, 1974; Koschman & LeBaron, 2002; LeBaron, 1998; Murphy, 2005; Scollon, 2001; Schegloff, 1988; Stevens & Hall, 1998; Streeck, 1993, 1995, 2009; Streeck & Knapp, 1992;). Sometimes speaker's gesture are for the recipient. They become speaker actions "for you".

Savas, an eight-year old child, who wants to play a newly learned card game with his mom, has articulated theories of gesturing that grounds this entire inquiry. First and elemental, gesturing is "just something we do". It is an organically human activity. We live in a body, live through our bodies, and live with our bodies. So it is no wonder that it moves with our talk and thoughts. Savas also articulates that gestures sometimes act to support the speaker's own thinking. For instance, when I speak to another, my gestures can be "for me" as I develop my thought and push it to language. He also articulates that gestures are used to communicate to another. That is, while speaking, my gestures can also be intended "for you." But Savas adds another layer of why he takes the time to use gestures to think through ideas and communicate information in interaction. He says he

uses them in this interactive explanation of how to play a card game “so you can actually play with me”. Once again, research reveals that gesturing and the body are also resources for achieving interaction (Chartrand & Bargh, 1990; Goodwin, 1997, 2000a, 2000b, 2003; Goodwin & Goodwin, 1992; Hutchins, 1995; Kendon, 1990; Schegloff, 1998; Stevens and Hall 1998, Stevens, 1999; Stevens, 2012; Scollon, 2001; Streeck, 1994, 2009). Savas seems to also know that the use of his gestures for explanation and understanding in interaction will get us to his end goal of playing the game with his mother.

The story of Savas explaining a game to me emphasizes that in everyday interactive explanations gestures serve multiple functions. These visceral acts of the hands can communicate and support thinking as they also shape and direct the interaction. Together, the overall, end-all achievement is ultimately a joint understanding that gives way to a subsequent action. Here, for Savas and me, the hands moving together with talk gets us something more than just communication and new knowledge – it gets us to the moment that follows when Savas sits down with his mother and plays a round of a card game. Gestures, thus, are actions performed in the world that help carry us to achievements, that can range from teaching and learning a game to play with a family member to negotiating the structure DNA.

The Questions That Shape This Project

The scene with Savas is somewhat similar to the cases I have studied for this project. It is an example of a teaching and learning interaction where one person (Savas) who has just learned something about something (in this instance, card playing) explains to another

who knows very little. It is further an example that in the process of teaching someone something new, participants employ multi modalities that include their hands and bodies. Savas and I were involved in an event that Stevens and Hall (1998) might frame as “disciplined perception”. For these authors “disciplined perception” refers to the intermodal activity participants employ in interaction when a more knowledgeable other is training a less knowledgeable other how to “see” in order to participate in that community. Savas’s gestures were, then, a resource to guide me toward being part of his community of card playing. The guidance was not just spoken; it was also *performed* through his body. That is, disciplined perception can be a kind of a performance genre that consists of “a set of specific forms of embodied action” (Stevens & Hall, 1998 p. 108). It is a performance where (as Savas shows us, and the data will further reveal), “cognition is “a property of the entire body in action...” (Stevens et al., 1998 p.109) and communication is enactment with the body. Starting with this view, I develop the idea of the hands and body as critical and diverse resources used to advance and organize teaching and learning in face-to- face teaching and learning arrangements for STEM disciplines.

In this study, I take the view that the activity of explanation is one process for disciplining perception. It can be a performative process - an in-the-moment performance akin to an improvisational development between the one who knows more and the one learning more. It is a multimodal duet where there are “forms of embodied action” that are passed back and forth until a level of perception (understanding) is communicated and ultimately achieved. Understanding how this happens is the motivation that drives this study. The questions that shape this study consider how people

participating across two conversations - one in which an expert explains a STEM concept to a non-expert and another in which the same non-expert re-explains the same concept to another – together produce, take up, re-use and adapt representational gestures to support explanation and concept formation in interaction. The study investigates how the body in the process of interactive explanations participates as (1) a communicative entity (the speaker performing an action “for you”), (2) as a resource to support thinking (the speaker performing an action “for me”), and (3) as an element to steer interaction to an end goal (the participants constructing action “for us”).

Gestures, of course, do not appear alone. Gestural activity is one of the many modalities in play in teaching and learning interaction. They are interwoven with spoken language, things, people, and experiences, and are understood within the webs of meaning these other resources spin. This dissertation is an investigation into how the gestural practice people employ for the achievement of meaning making and understanding. It is an attempt to explain how, by using our hands and body, we gather meaning and structure our environment, articulate information, share it with others, and organize our interactions. This project emanates from a focus on gestures that represent or depict an idea, action or object (I call these gestured depictions) in interactive explanations and expands outward to also include partnering modalities and contingent aspects of the interaction. The specific questions that have emerged from the preliminary analysis of pilot data are:

- How do gestured depictions used in interactive explanations get constructed and accepted as viable resources for explanation?

- Once established, how are gestured depictions used and adapted by both the maker and the recipient to achieve explanation and understanding?
- Do gestured depictions used in interactive explanations travel with the learner across time?

These questions are centered in the field of teaching and learning. There has been active research focusing on gestures across such domains of research as cognitive psychology, linguistics, and anthropology. It is only as of late, however, that the study of gestures has begun to slip into the field of educational research (e.g.: Alibali, 1997; Alibali & di Russo 1998; Alibali & Nathan, 2007; Cook & Goldin-Meadow, 2006; Crowder, 1996; Crowder & Newman, 1993; Goldin-Meadow & Singer, 2005; Hostetter, Alibali, Nathan, & Knuth, 2006; Kress, 2001; Lemke, 2002; Roth, 2001; Roth, McRobbie, Lucas & Boutonne, 1997; Stevens & Hall, 1998; Williams, 2012). Studies, however, are few and lack attention to a holistic, integrated use of gestures by both teachers and learners and as communicative tools and cognitive resources in interaction.

Research, mostly from cognitive psychology, has shown that gesturing and the body are very present elements useful for developing learner cognition in school-based subject matters (e.g. Alibali 1997; Alibali et al 2007; Arzarello et al 2005; Chu & Kita 2010; Cook & Goldin Meadow, 2006; Goldin-Meadow, Kim & Singer, 1999, Hostetter et al 2006; Lemke, 2002; Reynolds & Reeve, 2002; 2001). Other studies show gestures are present for communication and interaction for school-based discipline learning and teaching (e.g. Crowder 1996, Kress 2001; Kocshman & LeBaron 2002; Nemirovsky & Borba. 2003; Roth, & Welzel, 2001; Singer & Radinsky, 2010; Stevens, 1999; Stevens and Hall, 1998; Williams, 2008). Despite a plethora of studies emerging from varied

disciplines that address aspects of the role of the body in teaching and learning, the field of educational research and the Learning Sciences has not fully taken on the study as its own. As a result of borrowing different perspectives of the role of gesture from across disciplines some headway about the affordances of the role of gesture and the body has begun to take hold in the field of educational research and the Learning Sciences.

However, the results are piecemealed, either heavily focusing on gestures as cognitive resources or strongly attending to gestures as communicative acts. As teaching and learning is a complex enterprise dependent on the a dynamic exchange between communicative actions and meaning making processes, The fields of educational research and the Learning Sciences need to push toward a project of inquiry that examines gestures as concurrently communicative and cognitive and interactive tools. It is essential that the fields of educational research and the Learning Sciences not only use prior studies to directly frame and examine the functional role of gestures and the body for teaching and learning, but to also establish new frames, new methodologies, and new theories that directly attend to the questions, issues, and aims of educational research and the Learning Sciences. It is through the combination of past and current work in other disciplines being directly transported into the field of research for teaching and learning and then through the creative integration with the development of new work emerging out of issues and interests related to teaching and learning in naturally occurring conditions that progress toward understanding the role of the body in teaching and learning that new perspectives will develop. Such progress will lead to new designs that make deliberate use of the affordances of the human body as a resource readily available to teachers and learners alike, and as capable of being cognitive tools and communicative

tools. In the short of it all, such research can benefit the teachers and learners in our communities by making sense of how we can make effective uses of the readily available, and often already- used, resources of our hands and body in interaction.

Why Study Gesturing and the Body for Teaching and Learning?

I entered into the study of gestures for teaching and learning because my own experiences as an educator and a learner revealed to me that the body does, in fact, *do something* in teaching and learning. I found it fruitful to embark on an investigation of what that “something” is. Providing empirical research that helps explain how the body is involved in teaching and learning will not only help expand research on both the body and education, but more importantly, will add to an action in educational reform that produces new designs for teaching and learning that make use of, and expand upon, the valuable research across disciplines that has begun to reveal the affordances of the hands and body in teaching and learning.

I am positioned for this inquiry just as a educational researcher in the Learning Sciences, but also as a professional dancer, choreographer and practicing educator. For years I worked as a teaching artist in partnership with classroom teachers. I worked with writing teachers and designed curricula that used the body to elicit descriptive language. I worked in partnership with science teachers where in the classroom bodies became planets, hands became molecules. While working in the elementary schools, I, along with the teachers, became aware of a dramatic change in learning that took place when the body became part of the experience. This sparked my investigation to explain how and why this was happening.

I did not seriously turn my focus to the scholarly study of how gestures and bodily action can participate in the joint activity of learning and teaching in the sciences until I was made aware of its value to those in the business of teaching science. I was teaching a college-level choreography class for non-dance majors, that included two graduate students studying chemistry education. The students were assigned to observe the everyday movements of people around them and use the gestures and actions to inform choreography. The graduate chemistry students shared the gestures and bodily enactments each used to explain ionic bonding to a group of undergraduates. This sparked a collaboration in which the graduate students, the professors and I worked together to incorporate these gestured depictions into lectures and small group tutoring sessions. This development revealed to me that understanding the body as a participating member in the teaching and learning of science was of interest and value to those in that community.

STEM fields (Science, Technology, Engineering and Mathematics), particularly the sciences, seem to be an obvious setting in which to pursue this inquiry. The sciences are inclined to multi-modal teaching and learning practices by the very nature of the content. Charts, pictures, language, text, and models all participate in meaning making in the science classroom (Crowder 1996; Kress, 2000; Roth & Lawless, 2002; Stevens, 1999; Stevens & Hall, 1998). Science phenomenon is often not visible to the naked eye. Science phenomenon is dynamic, three-dimensional and temporal. And likely because of the nature of science knowledge, studies have shown that scientist do turn to the use their the body to incite concepts that are sometimes, more easily and more effectively manifested through the body in action rather than talk alone (Becvar et al., 2005;

;Goodwin, 1997; ; Kress, 2001; Ochs, Jacoby & Gonzales, 1996; Roth, 2000; Wells, 2000).

A handful of studies of science teaching and learning in the classroom are just coming to recognize the role of the body in instruction (Crowder, 1996; Koschmann & LeBaron, date; Kress, 2001; Roth & Lawless, 2002; Singer & Radinsky, 2010; Stevens and Hall, 1998). These studies particularly show that learning is achieved through an orchestrated process of coordinating representations. The body is one of these coordinating agents that links up external representations (Goodwin, 1996; Hutchins, 1995; Kress, 2001; Latour, 1976; Stevens, 2012; Stevens & Hall, 1998). Beyond simply coordinating external representation, the body in science teaching can actually be the material that the representations are made up of (Becvar et al 2009; Chu & Kita 2011; Ochs et al., 1996; Kress, 2001; Scopelitis, Mehus & Stevens; 2010).

When Amelia, one of the chemistry graduate students from dance class, showed me how she explained molecular bonding to her students, her right hand acted as hydrogen and her left hand acted as oxygen. But representational gestures are not just visual and observed. When Amelia had me use my hands as molecules and perform the representational action of two molecules colliding and then connecting, the action resonated through out my body. It became a visceral, felt experience as the representation became absorbed and incorporated in my body.

Such experiences turned my research attention to understanding how the body was involved in communicating and understanding science concepts in teaching and learning interactions.

Using the hands and body to represent information for science learning. I focus on the explanation act in teaching and learning as it is an activity dominant in the science classroom (Chi, Bassock, Lewis, Reimann, & Glasser, 1989, Horwood, 1988; Norris, Guilbert, Smith, Hakimelahi, & Phillips, 2005). I enter the analysis by looking at gestures and the body as resource for representations. Many have studied representations in STEM (e.g.; Kress, Charalampos, Jewitt, & Ogborn, 2001; Latour, 1990: Lynch and Woolgar, 1990; Stevens, 1999, 2011, Stevens and Halls, 1998; Stieff, 2010) and the idea of visual objects helping to construct knowledge is common in the field (Latour, 1995). What is less common is the study of gestures as representations and how knowledge is constructed in interaction with such bodily representations across teaching and learning arrangements. It is this phenomena this project explores.

Blending Perspectives to Study Gesturing and the Body for Teaching and Learning

Studying gestures is not a new focus of inquiry. It is, however, an inquiry that has recently re-emerged during the latter part of the 20th century (e.g. Birdwhistle, 1970; Ekman et al., 1972; Efron, 1941, 1972; Knapp 1972). With the resurrected interest in gestures as more than insignificant hand waiving, two lines of inquiry have developed that are most useful for the study of teaching and learning. These two perspectives for inquiry have taken an ontological view and a praxiological view. The ontological strand of research on the role of gestural practices focuses strongly on how gesturing supports individual thought. Researchers found that “gestures open up a whole new way of regarding thought processes, language, and the interaction of people” (McNeill, 1992, p. 12). The influential research on gestures often described them as a “window into

thinking” (McNeill, 2000). Gestures, according to this line of thought, reflect aspects of the gesturers’ inter-mental processes. Parallel to this frame of how gestures operate to support individual mental thought is a line of inquiry that treats gestures as socially situated significant acts of communication (Kendon, 2004; McNeill, 1992, 2005; Streeck, 2002; Goodwin 1986, 2000a, 2007). This praxiological view investigates gestures as action, particularly communicative action.

For the most part, both views have developed parallel to one another, only tangentially crossing. I believe that blending perspectives of gesture use is the only way to fully understand the phenomenon of how peoples use gestures and their bodies in the interactive process of teaching and learning. This project represents the natural course of progression when taking gestures and the body into the multi-modal study of teaching and learning. I integrate theories and develop them for research on teaching and learning. This allows me to make use of a broader conception for a focused inquiry into understanding how communication and thinking happens with the body in interaction for the achievement of teaching and learning.

I take the view, as experienced in my interaction with my son, Savas, that gesturing is a mode in everyday actions by which the world is structured, known, understood, explored, communicated and, finally and foremost, activated. I aim to do more than what most studies have done. I aim, from the view of an educational researcher in the Learning Sciences, to not only show that gestures and the body are present in teaching and learning. I also aim to understand how gestures and the body participate in the complex enterprise of teaching and learning within and across events. My hope is to

provide effective insight that can inform new designs and pedagogical practices, and inspire further discussions.

Despite the presence of empirical claims for the role of the body in thinking and communication, there is, although growing, a relative lack of research on the body situated in educational scholarship that takes an in situ approach. Much of it exists outside the direct domain of research on teaching and learning. And much, although valuable, is experimental. Studies of this nature, although revealing interesting findings, fall short from fully answering the question of the role of the body in teaching and learning because (1) they lack the everyday context in which teaching and learning happens and, (2) they are isolated in a particular discipline, concentrating most dominantly on gesture use as cognitive, or gesture use as communicative and interactional. This separation, as a result of interest in differing questions, raises a roadblock for fully investigating the body in education. Questions about gestures for teaching and learning require not only an investigation framed specifically for education, as others have begun, but also a blending of perspectives and methods. It is through the action of blending theories in which educational research can truly make significant advances in not only recognizing how teaching and learning happens across multiple modalities that include the body, but also in informing new designs and pedagogical practices that make use of the hands and body as vital, omnipresent forces in use for communication and meaning making in educational domains.

An Overview of the Study

The study employs the methodology of microanalysis of videotaped face-to-face interaction (Derry et al., 2012; Erikson, 1995; Garfinkle, 1967; Goffman 1983, Goodwin, 1993; Heath & Hindermarsh, 2002; Hutchins 1995; Jordon & Henderson 1995; Schegloff, 1987; Streeck & Mehus, 2004; Stevens, 1999, 2011; Stevens & Hall, 1998). This involves the fine-grained, qualitative analysis of sequences of talk and action. This process of analysis allows for the close investigation of moment-to-moment, turn-by-turn, interactional exchanges giving detailed information about what is happening in a particular instance.

I investigated how gestures that depict information are used in face-to-face interactive teaching and learning arrangements to achieve explanation and understanding of STEM concepts. I refer to these events as “interactive explanations”. The term “interactive explanations” expresses the position that the explanation of concepts can be a dynamic exchange between people, the context, and the resources available and activated in a teaching and learning arrangement. Explanations are not always monologic (Antaki, 1994) events that involve a speaker and a listener. They are events constructed in interaction. A back and forth interactive exchange allows for the planning, crafting and building of the explanation based on prior turns and actions of all participants. It can be likened to an improvised jazz session in which one musician takes the lead and the others step in, building off the lead and adding to it until a composition is achieved.

I frame explanations as having a discourse structure consisting of a beginning, middle, and end (Antaki, 1994; Heiser, Lee & Daniel, 2009). The beginning is an introduction; the middle is a step-by-step accumulation of qualifications and

specifications, and the end is an indication that the task has been completed. This explanation structure has been observed in spontaneous verbal instructions (Antaki, 1994) and through the use of diagrams and external representations as well (Tversky et al., 2007). In this study I adopt this three-part structure of explanation and examine how teaching and learning is achieved through a focus on the use of the hands and body.

I also show that gestures developed in interactive explanations travel across time with the learner to interactive re-explanations. (A finding not achieved at the time of this study). The study aims to shed light on how the body participates in teaching and learning in and across events as it slides between multiple and interchangeable, as well as interdependent, roles as a (1) communicative entity, (2) a cognitive tool, and (3) a resource to shape interaction. The study further aims to show that these roles and functions are dynamic and changeable based on the interests, goals, and contingencies of the changing roles and aims in interactions within and across events. This is valuable for teaching and learning in that it demonstrates that teaching and learning is interactively achieved across time as participants strategically and creatively employ the hands and body as vital resources for the joint achievement of explanation and learning.

The findings reveal how gestures and the body are complex, multi-functional resources that occupy dimensions for cognitive, communicative and interactional achievement and, as such, are viable resources for teaching and learning in face-to-face interaction. This sets a stage for further investigation into how gestural practices used to explain complex concepts in face-to-face informal interactions can be profitably extended to the teaching and learning of STEM subjects in other learning arrangements such as the small group tutoring session and the lecture classroom.

Outlining the dissertation. I have just laid out the brief premise of the study. In Chapter 2 I propose a frame for analyzing the data that considers the mind and the body as an holistic unit in a social system for learning. Starting with the theory of disciplined perception (Stevens & Halls, 1998; Stevens, 1999) I integrate, explain, and expand existing theories of Situated Learning, Distributed Cognition, and Actor Network Theory to help investigate the hands and body as resources in a social system for the achievement of disciplining perception in face-to-face teaching arrangements.

In Chapter 3 I review and outline the foundational research from which this project emerges. I provide a general overview of the study of gestures as it pertains to the present state of research on gestures and the body as object of study in research on teaching and learning, and as it informs my own study. I look at literature from linguistics and psychology that treats gestures as cognitive tools for individual mental activity and from anthropology and communications that highlights gesturing as significant communicative acts that happen in interaction. The two strands of studies of gestures cross both an ontological as well as a praxiological perspective on gesture use and serve to develop a way of examining questions of gesture use for teaching and learning that consider multiple angles.

In Chapter 4, I explain the study, giving information on how the data was collected and how it was analyzed. I also develop and explain terms used to make sense of the data in order to more fully attend to the question of how people use the hands in body in the complex process of teaching and learning in naturally occurring situations.

Chapters 5, 6, 7, and 8 are dedicated to the analysis of chosen data. In Chapter 5 I present Study 1 in which I analyze segments from three interactions in which experts

explain concepts in face-to-face, one-on-one conversations with a non-expert. This study demonstrates that gesturing and posturing are not just the unconscious by-product of a speaker's cognitive processes, but are also performed for communicative and interactional purposes that respond to particular contingencies of the situation and perceived learning needs of a recipient. As evidence for this strategic use of gesturing, I explain examples that show how gestured depictions (1) are built step-by-step, and that this building happens for and with the recipient. I further show (2) how gestures are used to correct the learner's misunderstanding (in response to the learner's gesture), (3) and how gestures are engaged by both the explainer and the recipient to drive the interaction toward the shared goal of achieving understanding.

In Chapter 6 I present Study 2 in which I apply assertions uncovered in the prior analysis of short segments to a single extended explanation in which Bram, an expert in chemistry, explains the fabrication of solar polymer solar cells to two non-experts, Raya and Ellie. This study further shows that all the categories of phenomena distilled from the prior analysis are also present in extended explanations, revealing that the role of gestures for teaching and learning is not a disparate phenomena appearing in only short instances, but also part of extended face-to-face explanations.

Chapter 7 presents Study 3. I turn to address the distinct question of whether gestured depictions from the explanation are carried in to the learner's re-explanations two days later. I examine Raya and Ellie's separate re-explanations and attend to how depictions preciously built in the explanation are used when the learner now takes on the role of explainer. First and foremost, the analysis reveals that gestured depictions do travel across time with the learner, suggesting that representations made by the hands in

interactive explanations are a seminal aspect for communicating and understanding the concept. The analysis further reveals that the gestural take up and variations of the gestured depiction function differently for the learner now as explainer than they did for the expert as explainer. The learning not only makes use of the gestured depictions to communicate information to the recipient, but also to organize and make meaning of newly acquired information in interaction, revealing the flexibility of the use of gestured depictions as communicative tools, as cognitive resources, and as interactional guide posts that are shaped by the contingencies and aims of the situation.

Chapter 8 concludes with Study 4. This study moves from a close study of one case within the data corpus to look at three other cases across the data corpus in which experts explain concepts to non-experts and the non-experts subsequently re-explain to another. The analysis sheds further light on how and when gestures function in teaching and learn arrangements for explanation.

In the Chapter 9 I bring all the studies together. I discuss the collective findings and their implications for teaching and learning. I provide further points of inquiry into how gestures and the body work toward teaching and learning for the explanation and learning of complex scientific concepts.

Expectations of this project. As my son, Savas, came home from school the other day, I asked him the proverbial parent question, “What did you learn in school today”? He answered, “angles”. I then asked the educational researcher question,

“How did you learn it?”

“Mr. Carlson just told us the definition and showed us a picture.”

My expectation and hopes for this project is that findings and questions emerging from the analysis stimulate further questions and inform creative designs that make use of the body and other resources from the material and social surround and strategically draft them into service in an interactional, multi-modal teaching and learning experience.

Perhaps what emerges from this study is that next time Ms. Carlson, instead of just talking about obtuse and acute angles, enriches the teaching and learning by building with her students an embodied depiction of the what it means to be an obtuse angle and what it means to be acute angle.

CONSTRUCTING A THEORHETICAL FRAME AS RESEARCH TOOL

[The mind] is formed out of commerce with the world and is set toward that world;" it should never be regarded as "something self-contained and self-enclosed. - John Dewey (1934, p. 269).

*Well, what do you think you understand with? With your head? Bah
- Nikos Kazantzakis, Zorba the Greek*

The body says what words cannot. - Martha Graham

*Cognition is a property of the entire body in action, a body shaped by participation.
- Stevens & Hall 1998 (p.108)*

Introduction: Weaving Together Theories of the Body

Following I define a working theoretical perspective for investigating questions about how gesturing and the body function for teaching and learning in face-to-face interactions to support the disciplining of perception for new learners in STEM fields in face-to-face interactions. I piece together a theory of the body as an interactive participant in the teaching and learning by integrating concepts established in theories of Situated Learning, Distributed Cognition, and Actor Network Theory with the idea of Disciplined Perception. Through the weaving together of such ideas, I am able to establish a frame in which to study how people use their hands and bodies in interactive explanations for complex STEM concepts. Collectively the theories help conceptualize a way of viewing the varied functional properties of the body as part of, multi-modal, multi-party achievements that happen in the mind as well as in the body and in the world.

Building From the Theory of “Disciplined Perception”

I begin with a social theory of teaching and learning – the theory of Disciplined Perception. Stevens and Hall’s theory of “disciplined perception” developed as an approach for understanding how people learn to participate in practices of techno science (Stevens & Hall, 1998). The theory takes into account the role of the body. Adopting the theory of Disciplined Perception gives me a frame to talk about how experts and non-experts use their bodies to negotiate discipline knowledge in interaction. I hang onto this frame other theories that give me the opportunity to extend the idea further into considering in more detail the role of the body for teaching and learning in interaction.

The term “disciplined perception” refers to the intermodal activity participants employ when a more knowledgeable other is training a less knowledgeable other how to “see” in order to participate in a particular discipline. The word discipline takes on two meanings that comprise the theory. When using the term discipline as a noun, discipline refers to the disciplinary make up and organization of a field, subject or specialty. Disciplines are constituted by particular knowledge, language, practices, norms, and goals. When using the term as a verb, discipline refers to the training and instruction of how to think and behave within the field in order for one to become proficient in order to contribute to it. The theory thus subsumes that not only are disciplines specific communities of practices, but also that to become part of the discipline newcomers must undergo a process of training and learning to be able to perform in the discipline.

The term “perception” refers to ways of seeing. Ways of seeing emerge as participants build and organize perspectival stances within endogenous communities of practice (Goodwin, 1996) in order to communicate and understand (Stevens & Hall,

1998). Stevens and Hall make the point, as does Goodwin, that to be proficient in a discipline a member must (1) be able to evaluate what must be treated as properly visible or invisible, and (2) be able to draw salient discipline information from what they see. Ways of seeing and perceiving can be rendered possible through a coordination of tools and representations. Goodwin (1996) illustrates this as he shows how two-archeologist work together to determine the category of dirt to inform its age. A trowel is used to collect a sample. Water is poured into the dirt sample to highlight the color. A munsell chart is used to compare the collected sample of dirt and determine its definition. What is central to this study is that the coordination of tools and the rendering of different representations are made active through the body (Goodwin, 1994).

Connecting the uses of the term “discipline” with this concept of “perception”, Disciplined Perception is then a theory of teaching and learning that gives attention to the trainability of ways of seeing in order to participate proficiently in a given practice. The theory highlights that the process of learning to see is a process in which one person who knows more about one thing works to organize another person’s way of “virtually orienting to the disciplined world” (Stevens et al., 1998, p. 141). Persons in interaction can work to organize understanding not only through talk but also through the use of the body. Stevens and a Hall show that when a recipient of the performed course of action demonstrates a similar performance, it shows that the intended import of the speaker’s action have been taken up either in part or in whole by the recipient – thus a demonstrating a level of learning.

I expand on the base frame of Disciplined Perception as an interactional and multimodal theory of teaching and learning as it recognizes the body as part of this

activity. I do this by recognizing ways the theories of Distributed Cognition and Situated Learning and Actor Network Theory also consider, although not always explicitly, the role of the body as an active element in a populated socio-cognitive network. I meld together ideas from each to construct a conceptual frame to understand the body as an element in the world and of use in interactive explanation. It is the integration of all these concepts that frame my analysis of the data.

Considering Thinking as More Than Just in the Head

I embrace the view that the activity of thinking can exist in multiple places simultaneously. It can be an activity in the head as well as in the body, in the individual as well as in the collective, in the being as well as in the world, and in the interplay between resources and domains. Taking this view, however, requires attending to other constructs that have a strong hold on how we have viewed learning as primarily individual and mental. Any research that attempts to uncover questions related to the body and thinking inevitably slams into the dominant and more-often accepted-rather-than-challenged construct of the mind and body being dual, asymmetrical entities. That is, the mind as the property for cognitive and rational thought; and the body as the domain for affective and base experience. This view of the body, saturated with the residue from traditions in Western philosophy and Christian theology, relegate the body to a position inferior to the mind. It has allowed us to consent to the mind as evolved and the body as less so. I avoid this separation of the cognitive mind from the affective body, the physiological body from the phenomenological body and accept them as one in the same.

It is not only the residue of a theory of the mind as cognitive and primary against the body as affective and secondary that positions the body on the periphery when educational research comes to examine how teaching and learning happens. Further constricting are the early developments in cognitive science that have made thinking processes analogous to the computer's processing of information. Here, the mind is seen as a computational unit locked inside the head, further distancing the body as a central participant in the process of teaching and learning. Following, I extend the trajectory of some contemporary thinkers such as Hutchins, Latour, and Lave and explore a re-conceptualization of the body as an equally active, responsive, and enlivened element in a populated cognitive system.

I turn to research coming out of domains such as philosophy, neuroscience, and brain research that have shaken up this view, suggesting that the body may have more to do with thinking processes than previously held (e.g. Clark, 2008; Damasio, Evertt & Bishop, 1996, Glenburg & Robertson, 2000; Johnson & Lakoff, 1999). This idea has posed a productive challenge to those disciplines where the study of learning was first built on a construct that cognition is an individual, mental activity that exists in the head, pushing ideas beyond this. In light of such recent shifts in theory across disciplines, the body begins to move to take a position worth examining. For instance, cognitive psychologist no longer disregard gestures and bodily actions as completely, inconsequential and meaningless hand waving that get in the way of thinking. Because of the work begun by McNeill, gestures come to be seen as part of cognition (McNeill, 1992, 2005). Staying in line with the idea that thinking is still primarily inside the head, gestures come to be studied as outward expressions of mental thought. That is, gestures

are regarded as assistive support for mental activity by triggering individual, mental schemas to achieve concrete, individual thought. In this view, the body does not become a thought-maker, per se. Thought still belongs to the space inside the head. The body, however, is recognized as tangentially participating in cognition. The commitment to this perspective has done quite a bit to give the body a place in thinking. It still, however, keeps a hierarchy operating where the thinking-is-in-the-head construct assumes the highest rung on the ladder for processing information. The body still falls somewhere below the mind, but not nearly as far. Accepting that the hands do reflect internal thought, but disregarding the body as always a handmaiden to thinking, I turn to other theories to continue building up a frame that will best help uncover how people use the body in teaching and learning interactions.

“Embodied Cognition”. I first turn to theory of “Embodied Cognition” developed out of Cognitive Science (see Wilson for further discussion). This theory, although possessing different permutations across different thinkers, developed out of the cognitive science perspective and still holds onto the idea that thinking involves a computational process. The body just becomes viewed as an input mechanism. The body becomes a perceptual tool, gathering sensory motor information, thus giving credence to the idea that the body is part of thinking. However, this view can often be stifled because it does not fully escape its legacy, and thus runs the risk of falling short for fully investigating the complex capacity of the body in cognition. The space inside the head as the unit for thinking still sits above the body in a superior position. Internal mental processing is still the penultimate port for complete and concrete thinking. The body

here becomes a link on an information highway delivering felt information from the outside the world to inside the head.

Such theories of Embodied Cognition that come out of the field of Cognitive Science try to reconcile the mind-body duality by positioning the body as a valid support to mental thought. They do not, however, fully work to explain what has emerged in the data I examine. The ideas are quite valuable but provide only part of the story of how the body is involved in how we think and learn. I thus turn to a growing body of literature on “situated cognition” and “cognition in context” (e.g., Lave & Wenger, 1991; Hutchins & Palen, 1998; Stevens & Hall, 1998; Stevens, Satwicz & McCarthy, 2007; Williams, 2010) that adds another layer to the idea that cognition is only a series of processes that gets played out in the head. Thinking also happens in the world, in the body, across individuals and with the collaboration of other resources. The idea of internal mental processes and bodily experience existing on a hierarchical, linear, progression towards thought gets replaced by the idea of the whole person acting as an integrated unit in and with the world.

One of the objectives of this study is to provide some evidence that one perspective alone, thinking in the head and thinking in the world, does not explain the multiple complexities of what is happening in face-to-face interactions when gesturing is employed to achieve explanation understanding. I blend views and embrace a phenomenological perspective that considers gestures to be not just reflections of thinking or supporting elements for mental activity but that bodily activity can be thinking in itself. I identify cognition as also being phenomenological and intrinsically taking place in learners’ moment-to-moment interactions with objects in their

environment (Goodwin, 1997, 2003, 2007; Heidegger, 1962; Stevens & Hall, 1998; Varela, Thompson, & Rosch, 1991). I position knowledge as residing in both the mental and physical experiences that exist in these interactions (Hutchins, 1995). I also invoke a praxeological approach to gestures (Becvar, Hollan & Hutchins 2005; 1990; Heath, 1986; Latour 2005; Lave 1988; Stevens and Hall, 1998; Stevens, Satwicz & McCarthy, 2007; Streeck, 2009; Williams, 2010). Ultimately, I locate meaning-making and thinking, not only in the individual, but also in the practices, actions, and experiences of participants within a socio-culturally constituted, social and material setting of the world.

My analysis illustrates perspectives that a blending of the ideas of thinking being an individual and mental act with thinking as a socio-cultural, multi-resource, multi-modal, activity” provides a more comprehensive frame to better understand gestures use in the activity of teaching and learning.

Incorporated thinking. Taking the idea of Embodied Cognition (see Wilson, 2002) further and not only acknowledging that the body can be a conduit, or mediator, for thinking, I also add the conception that the body can be, in fact, a self-supporting locale where a bulk of thinking takes place. Knowledge can be also be fully incorporated in the being, bringing the body to the position of a thinking entity within itself. One way views like Embodied Cognition blend body and mind is to consider the body as a mediator for thinking as it holds abstract thoughts that become concrete once delivered to the mind’s doorstep. I accept this classical view and add on. It is not that the body holds only abstractions. This perspective alone leaves us with the conclusion that knowledge in the body is less grounded, less concrete, and less complete than knowledge that exists in the mind (Streeck, 2009). And this is not sufficient. I take the view that knowledge in the

body, not only an abstraction of its later development, can also be concrete and stable and complete. It simply concludes in forms are thought that are not linguistically based. The forms the thoughts take, when residing in the body, are haptic and kinesthetic rather than linguistic and mental. It is important to highlight that the modes for experiencing knowledge are different, (one linguistic, that other bodily) but not the state or quality of thinking. I frame the analysis that knowledge can be experienced both mentally and incorporated viscerally in the body. I take the view that when we come to see the entire person, not just the brain and mind, as subjects and agents of thought, then we can better decipher how teaching and learning is a holistic process that exists in a broader system than the mind itself.

In Stevens and Halls theory of disciplined perception, underlying the analysis is the recurrent theme that the hands and body are part of knowing. Changes in knowledge are registered, not just in the mind, but also in the body. And the body, like the mind, is an instrument that, through experience and guidance, is disciplined to be aware of its affordances for learning. Latour defines the idea that the body learns to experience knowledge by defining the body as a unit that “learns to be affected” (Latour, 2005). The body too, then can be “disciplined” to “perceive” and trained to communicate.

We can envision the body as having the capacity to be sensitive to differences and to be keenly aware of nuances. It is a potential instrument for teaching and learning. An example of “learning to be affected” is the training of a perfumer (Latour, 2005). Over time and across exposure to other elements the body, here the nose, learns to be discerning of odors. It becomes a discriminating and knowledgeable instrument in the process of perfume making that helps achieve the action of creating “eau de toilette.”

Another example of the body learning to be affected is when the surgeon learns to make an incision. Making an incision includes attending to the felt experience of the knife against the skin in order to determine how much pressure to exert. In the process of developing knowledge, it is necessary that the body continually be allowed to “learn to be affected”. This view not only acknowledges the body as a primary player in knowledge building but also accepts the premise that thinking is an activity that happens in interactions with things, actions, and people.

Considering the Hands and Body as Players in a Distributed Network

I take the stance that learning happens in the activity of being in the world. My epistemological premise is that knowledge exists in activity and is constructed through the relationship of people, things, contexts, and histories. Included in this assemblage of things, people, contexts, and histories is the human being in her body. When discussing learning and teaching as an activity in the world, the body and the person, in all its complexities must be included. Although, this seems to be a natural inclusion, as we cannot escape our body, only recently have we seen the action of the hands and the body receive empirical attention in teaching and learning events as players in the distributed network (e.g. Goodwin, 1997, 2000; Ochs, Jacoby & Gonzales, 1996; Stevens & Hall, 1998).

I first turn to the two theories – that of Distributed Cognition (Hutchins, 1995) and Actor Network Theory (explored by such people as Callon, Latour, Law and Sisondo) as starting points for creating a frame for analyzing how the body participates in the activity of teaching and learning. The basis of both theories, although neither a

direct theory about the body, presents structures that can contain a theory of body for teaching and learning. In between these theories I bring another helpful perspective for a theory of body for teaching and learning as represented by Chuck Goodwin. It is a theory of “situated action” (1999) where action is located in interaction and accomplished through interweaving resources that include the human body in action. These views together offer a base for further development as I construct a frame for considering the body as an intimate player in teaching and learning worthy of detailed examination.

In the spirit of all these theories that consider experience in the world, I approach my outlining and development of these perspectives for frames for understanding the body by invoking my own experiences in and with the world. In the discussion of each perspective, I first lay out key components of each perspective. I then explore the viewpoints more closely with the body in mind by using my experiences as a dancer in a professional multi-media performance company. I then take both the theories of Distributed Cognition and Actor Network Theory and use each as a lens to examine a video segment from my data corpus. Finally, I round out these theories as frames for studying the body in teaching and learning by discussing empirical work that has launched off theories developing ones to put into practice to look at the body in interaction.

I have spent time discussing the body as cognitive resources against the mind. The body, as the premise of my frame for analysis claim, is not simply a cognitive resource but a communicative and interactive one as well. Following I explore theories that support this and give me fodder to develop such a position further.

Distributed Cognition and the body. Hutchins (Hutchins, 1995) systemized a frame for rethinking thinking by locating cognition in everyday activity and pushing the unit of analysis of cognitive activity outside of the human mind to include what is happening in the external world. Developed out of the work of Bateson, (e.g. Bateson, 1963, 1972) and others, this theory of cognition is shaped by the idea that learning is a socio-cultural endeavor and that knowledge is a dynamic, collective, social activity that is constructed in the process of interaction among people, things, culture, and context. The activity of cognition is distributed amongst all such elements as each part contributes to the whole task.

Distributed cognition develops out of the idea that the basis of cognition is about processing representations, either sequentially or in parallel. Two components of the theory are that (1) information is embedded in representations in and outside of the mind, and (2) these representations get coordinated in interaction. The following discussion will address where the body falls in terms of these components of the theory. The theory starts from the central hypothesis of cognitive science that claims thinking can best be understood in terms of representational structures in the mind and through computational procedures that operate on those structures. Hutchins splinters off from this perspective and suggests that these operations are not relegated to the individual mind alone. He adds that a framework for thinking about cognition requires that we consider the external environment with all its components –artifacts, history, context, culture, emotions, and cultural tools. He makes room for the study of the body as part of this activity. As Hutchins' theory attempts to re-fine and expand on the dominant view of the mind-as-computer metaphor as it quarantines thinking to the brain, he acknowledges that a huge

flaw in this view is that it completely deletes the body. “The hands, the eyes, the ears, the nose, the mouth, the emotions all fell away when the brain was replaced by the computer” (Hutchins, 1995, p.363). He concludes that as a result of this deletion, we do not get a full view of cognition. He aims to expand an holistic view of cognition.

Hutchins’ first step was to move the unit of analysis away from the individual and to the socio-technical system. For instance, in his study of the cockpit of a plane (1995) the collective functional task at hand is to remember the plane’s speed. The task, Hutchins shows us, is distributed among people and things. One instrument can calculate distance. Another maintains records of speed. Another instrument can indicate location. And the pilots can coordinate actions and information in a desired sequence. The effectiveness of the task is thus dependent upon the performance and the coordination of the elements within the system. Elimination or a break down in of one of these elements results in a failure of the task to be achieved correctly. Thus, it is the system that achieves the task and not the individual alone.

By locating cognition among the activities and tools present in social activity, knowledge comes to be a collection. And by this very nature of it being a collection if the distributed parts add considerably more to thinking and thought than the properties of the individual does alone. For me to expand on the idea of distributed cognition and the role of the body, I invoke my own experiences and histories. As Hutchins turns to his practice as a pilot to develop a theory, I look to my experience as a dancer in a professional dance company to further distill out the theory of the body from the theory of distributed cognition. I apply the theory to my experience in a system where the body is an obvious resource in the system —dance. The socio-technical system is the dance company in

practice in a studio. The functional task is recalling repertoire. Invoking the theory of Distributed Cognition, I ask, how does a dance company remember a dance?

First, the body can act as a memory instrument. Some of the information and knowledge of a lost piece of choreography is distributed to the people and their bodies that have participated in the choreographic work. One body, however, usually does not hold the full record for the entire choreographic work. In reconstructing a dance, all the information embodied in the person needs to be coordinated. I turn to my experiences as professional dancer to illustrate this point. I recall having to resurrect a piece entitled “Gallery” when I was a member of a dance company. It had been a couple of years since we last performed the work. We decided to “walk through” the dance together to see what was remembered. Parts of the choreography came back to life but other parts were lost. For instance, I remembered the first part of a movement phrase and Donna remembered the next. Kay and I recalled that we need to change our facing but we could not figure out on what musical count we changed direction. The system is breaking down because the bodies, although maintaining some parts of the dance, have lost other parts of the work.

Tito decided to turn on the music. Donna yelled, “The direction change happens on that ding!” Can some of the choreography be resurrected through the music? Hutchins would certainly think so. We also have documentation of the dance from a prior performance. But the videotape of the last performance of “Gallery” is dark. Only parts can be seen. But we can still look at the videotape and see what our mind and bodies forgot. It seems that part of the dance resides in the videotape as well.

Taking on the perspective of Distribute Cognition, the dance was reconstructed by pulling in the knowledge that was distributed among the parts. The body is one of those parts that hold the knowledge of the dance. The practice of dancers remembering a dance provides examples of thinking and reasoning via the use of the body in the material and social world. Does a similar use of the body happen in cognitive systems where the body is traditionally not thought of as being central to the system? I now move to the scientific community. Here the body is not thought of as being a critical tool in the distribution of cognition and knowledge. But we do know that the organization of communication media and the distribution of cognitive activity between people and inscriptions account for much of how teaching happens (Kress et al., 2001). Can the body act as communication media and assume the similar role as other inscriptions such as graphs and models and charts?

As the body can act as a container, holding information in a distributed system, the body can also act as material for representing knowledge. Hutchins poses that a knowledge task is achieved “by the propagation of representational states across a series of representational media” (Hutchins, p117) externally available. A medium for representation can be the hands and the body. I turn to a segment of data from the corpus I collected for this dissertation to demonstrate this idea. Sakina is explaining DNA structure to Sari. At one point, Sakina represents DNA structure in an equation, another point as a two-dimensional picture on paper, and at another point as a three-dimensional object made by the hands. The representation cycles through different media until Sari arrives at an understanding. Here a single concept moves through varied material,

including the body. But representations can also be cycled through just the hands as the material.

Sakina is explaining the architecture of DNA. Sakina's first step is to make a structure of DNA – here is representation 1 made by the hands. She then flips one hand over to show anti-parallel strands – here is representation 2 made by the hands. She then drops out a hand and uses the index finger to become a pointing tool to direct gaze to a point on the other DNA strand – here is representation 3 made by the hands. Collectively they build a fuller explanation of DNA structure for Sari.

This demonstrates how a distributed cognitive system can involve the body as a resource for representations. The body becomes one of the mechanisms that may be summoned to participate in cognitive processes.



Figure 2.1. Cycles of representations

The body and hands can also act as coordination instruments. According to the theory of Distributed Cognition, representational media needs to be coordinated to achieve a task. These representational states are propagated from one form to another by being brought into coordination with one another. The body participates in this “in-the-moment” coordination and interweaving of representational media as a means to achieve a common goal. As Hutchins shows in *Cognition in the Wild* (1995), in coordinating representations of a fixed cycle on the navy ship, fingers point to places on the map,

bodies move across the ship to deliver information. A drawing motion with the hands over a map enlivens it. Pieces of paper filled with essential information are passed across members of the crew. As a result of this dynamic activity of coordinating representations, the task of plotting a ship's location gets moved along and completed. Here the body can act as an instrument to coordinate the various resources and media representations in the environment. In the sequence of action represented above, we see the body interchangeably acting as the representation as well as the coordinating actor to link the representations. For instance, when Sakina drops out one hand of the DNA model she re-appropriates it as a pointing tool (see Figure 2.1). As the hands can shift instantaneously from one role to the other in a system – from being a representation to coordinating representations – the body can be a complex and shifting resource in the network.

Not only are gesture constantly changing resources in the network, they are also complex in that the gesture is always attached to the gesturer. It becomes impossible to disambiguate the maker from the gestured depiction, obligating the research to consider both the gesture and the gesturer in analysis.

W.B. Yeats's poem *Among School Children* (1926) concludes, "O body swayed to music, O brightening glance, How can we know the dancer from the dance?" In the poem the speaker raises the question about the location of life. Is it in the single person or the coordinated action of the dance? Yeats suggests that the two cannot be separated. The dancer is the dance and the dance is the dancer. We can say the same about the action and meaning across the gesture and the gesturer. This adds another layer of complexity to understanding the position of the body in the cognitive system. The hands

as media for representations act both as the material of which a representation is crafted as well as the tools that craft the representation. They are both the “thing” and the “maker”, simultaneously. In terms of Hutchins’ view, here are two elements of the system that are bounded and shaped and inhabited by one another. I now ask how might a theory of distributed cognition treat this inter-relationship of two elements that can slide into different roles in the moment-to-moment changing interactions? This makes the body a very different kind of communication medium than a graph or a constructed model.

Like a dance, a performed gesture is here and then gone. Gestures are ephemeral representations. They do not stick around in their material form like a picture does. They cannot get recorded like marks on a paper or information in a hard drive. At best, they get recorded subjectively through memory or sensory-recall. They can certainly get picked up again. And like remembering the dance, the gestured object can be picked up with unintended differences. These attributes of gestures and gesturing make the body a very complex and unique tool in the cognitive system. It has flexibility and immediate availability (because the body is always with us) and can be summoned quickly and adapted instantaneously. But it is unstable and fleeting as well. This, for me, introduces another layer of the cognitive system, the negotiation of information and the stabilizing of representations made by the body.

The theory of Distributed Cognition with its premise that things, people, activity, context all participate in knowledge construction and task achievement is a fruitful and useful frame for exploring the body in the cognitive network. The body can hold information, represent information, and coordinate information. The theory also is helpful

in that Hutchins does not destroy the cognitive science model of cognition and completely pull it out of the individual mind. He simply expands out on it. For him some of the structures involved in the systems are internal to the individual and some are external. Some of the activity that goes in to the completion of the task includes not only the external instrument to get the task done but also internal structures. Hands are interesting because they exist at the same time outside the individual as resources to be acted upon and with, as well as something inevitably connected to the individual. It seems to be a site that crosses between the internal and external – the operation that happens within the mind and the ones that go on outside of it. And as the theory of distributed cognitions involves the coordination between internal operations and external structure and processes, it allows for a kind of perspective that can, as I am interested in doing, link the internal with the external when we discuss gesture use. It also can act to bridge the distances between those taking a pure cognitive view and those taking a weighted social and situated view.

That being said, I believe that an analysis based purely on Distributed Cognition, falls somewhat short. As it does offer us a unit of analysis that takes us outside the mind and into the world, its base in computational processes for explaining cognition may not be enough to explain all the complexities involved in gesture use for teaching and learning in interaction.

Actor Network Theory and the body. Actor Network Theory (ANT) is a theory of emerging organization that seeks to explain social arrangements through dynamic networks of connections and associations between human agents, technologies, and objects. Some basic proponents of ANT are (1) entities and agents can be both human

and non-human, and (2) entities do not exist in isolation but rather gain form and acquire attributes as a result of relations with other entities. That is, objects and actions are not defined by their shape, place or positioning in the social network but by what they do, how they act on, act with, and act through other entities in the network.

ANT is concerned with how a network comes into being. It not only attends to what assemblages and associations need to be made in order for actions to take place but how these associations and connections are made. In a study of scientists in the Boa Vista forest, Latour, (1995) points out the levels, layers, and combinations of symbols and signs and action required to conduct specific scientific research across settings and over time. He shows that in this network of associations the body is an active participant.

In the next pages I set up an imagined conversation with a professor, who studies how teaching and learning happen and is an expert in ANT, and myself, a student in ANT studying teaching and learning. I borrow this idea of creating a dialogue to explain a concept from Latour's book *Reassembling the Social* (2005). I also use this format as it reflects the nature of the data I analyze – face-to-face explanation conversations. In this fictitious yet possible face-to-face interaction, there are combinations of symbols, signs, words, actions, and social interplays that get put together to explain an idea. I elaborate on this as a way to outline how this aspect of ANT can offer a useful analytical frame to investigate the body in a network where teaching and learning happens.

“An interlude for dialogue”. I meet my professor at the local coffee shop. We each sit down with our cup of coffee. He begins our conversation by invoking a metaphor to explain Actor Network Theory. “Let’s imagine a network as a star-shaped constellation of points and pathways.” He reaches for a piece a paper and begins to place

dots that radiate from a central point. “A network is defined not by the entities or the points here.” He taps a dot with the tip of his pen. “It is defined by these pathways.” His hands zoom over the drawing like two racecars in the Grand Prix, “that allow for associations, connections, and assemblages. “And to be more precise, ANT is not focusing so much on the pathways themselves but the action and work that goes into constructing these pathways and creating associations.”

I immediately comprehend this image of the network as a living, breathing, moving, and morphing entity. As I think of this, I become aware of the slight and almost unperceivable movements of my body as it swirls and circles. It is like my insides are liquid (the idea seems to have been absorbed and incorporated into my body and my understating becomes visceral). I think about the pathways and associations. They appear to me to be like snail tracks or contrails in the sky— leaving a slight imprint of their pathways behind. Mr. P leans forward and speaks. “The network is like liquid. And the pathways made are like water marks tracing the action,” he says.

“The actor in Actor Network Theory can be either human or non human entities. Nothing human-centric about it!” he adds. He looks around and as he speaks he points to the things he lists. “You and me, the waitress, the tray the waitress used to carry our coffee, the machine that made our coffee, the man who operated the machine that made the coffee. This network we are in right now includes the table we sit at, the coffee plant back in the Boa Vista village, the bean on the plant and so on.” He smiles at me playfully. I smile back. He sounds like Alwin Nikolais , the multi-media artist I danced with. Nikolais’s work decentralized the human and treated technology and props as equal players in the theatrical event. Could this be a model for ANT?

“Now, all actors, human and non human, have interests, often many interests at the same time. Interests are like trajectories. They are kind of like intended pathways. So we always have that dynamic going on of active and multiple interests floating in the space and vying for conclusion.” With his hands, he does a rapid zooming, curricular motions in the air as he speaks this. “In order to achieve organization in the social activity, all these interests need to be managed.” His hands crash into one another and then drop to his lap. He utters a child-like giggle. I get the point.

“Also present in the network are intermediaries and mediators.” He reaches for the sugar bowl on the table and places it deliberately in front of me. He takes two napkins, and one spoon and positions them intently on the tabletop. I lean inward to focus in on what he is setting up for me. “Action passes through intermediaries.” His fingertip traces a pathway from the spoon through the sugar bowl to the napkin. “In the transport through intermediaries nothing really changes. Intermediaries simply allow for a transport to happen. A mediator, on the other hand, creates an association that ultimately changes and alters the network by disrupting it.” He swiftly and randomly re-arranges the objects on the table.

I think of a piece I performed with the Nikolais Dance Theatre called Tensile Involvement.

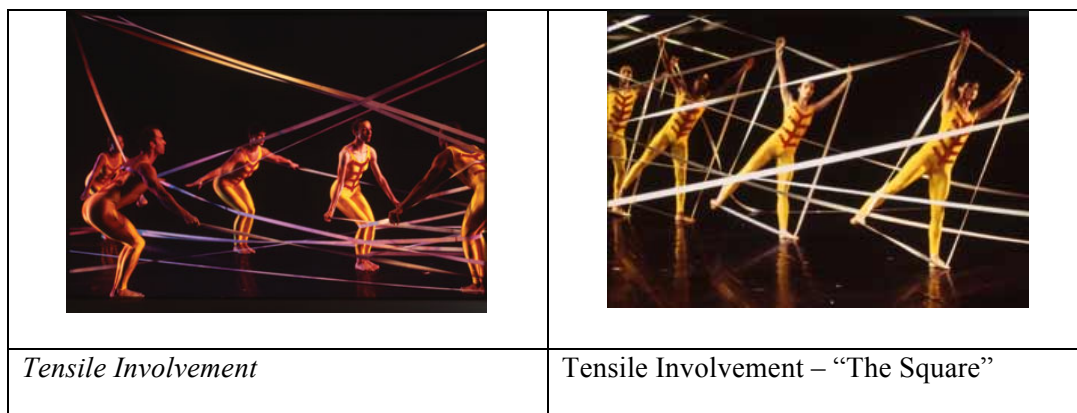


Figure 2.2. *Tensile Involvement*, choreographed by Alwin Nikolais

Eight huge elastic bands fill the stage from floor to ceiling, from stage left to stage right, from down stage to up stage. The dancers and the elastic bands are moving together, each indistinguishable from the other. Sometimes the dancers move the bands and sometimes the bands move the dancers. The effect is like a huge changing cat’s cradle. In the performances of the choreography, any slight mistake, such as a dancer in the wrong place at the wrong time, and the dance fails. If my elastic goes under Simona’s in the first minute of the dance, I can’t make the “squares” in the fifth minute of the dance. The disruption changes the dance -- not a desired outcome. In rehearsals we prepare for these disruptions by re-enacting the possible mistakes. I could trace the failure of making the square to the point in time when Kay, Simona and I cross. On the musical count six I must step over her elastic and under Kay’s. Successful coordination of everything results in achieving all the interests.

The elastics and the timing are elements acting as intermediaries, transporting the interests of the actors to a desired end. If I cross on the musical count eight and not six, or step over rather than under the elastic, then the elastic becomes the mediator of an action that changes trajectories. This disruption leaves a trace to reveal the action - a trace we investigate in rehearsal so the disruption does not happen again.

Now the dance piece as a metaphor eventually breaks down because the action and trajectories have already been spelled out. They've been choreographed. The interests in moment-to-moment social activity are not a choreographed dance. They are probably more like an improvisational scene.

A month later I meet my Mr. P at another coffee shop. He is late. I joke around with him and ask him which intermediary he took to get the cafe. He smiles and says "The F train." We both laugh. This leads to a discussion about how action is accomplished through associations and transport. How do things as agents get activate and mobilized?

At this point the woman behind me bumps my chair as I bring the coffee cup to my lips. Coffee spills all over my lap. I excuse myself, and head to the women's room. I have doused the coffee spill with clean, cold water. I look for paper towels. All I see is a self-activating hand dryer. I slip my wet knee up to the dryer and wait for my pants to dry. I don't do anything but wait. The act of drying my pants has been transported to the automatic dryer. In fact, the act of starting the dryer has been transported to the action of placing my knee under the funnel. I think I am getting it!!! Can I think about the hands as a kind of technology as I analyze gesture use in interaction for teaching and learning? I smile because I think I certainly can.

Hands and body connecting the network. In this study I employ aspects of ANT to help analyze the body in teaching and learning. ANT, however, is not a theory of learning and teaching, per se. It is, however, a way to look at social organization and human activity and this is inevitably at the heart of teaching and learning. Following, I look at the familiar data to show how an ANT-inspired definition of learning as a social

activity that happens through the making of associations can help uncover what is happening in the data that is central to this project. I return to the Sari/Sakina discussion.

In the discussion of crystallization of DNA there comes a point in which participants realize that the task of Sari understanding crystallization cannot move along successfully until Sakina explains the structure of DNA to Sari. The obvious basic interests, although one of many, of these human agents is embedded in the practice of explanation – one interest is to get to mutual understanding. Although other interests are in action, no traces of these are evident in this particular segment. But just to push the investigation, I move to an earlier point in the clip. Here Sari gets out of her seat to adjust the camera – here is a trace that suggests that another one of Sari's interests is to get the conversation on videotape. To play out ANT, the camera is also an agent in this activity. The camera's interest is to record the conversation, and the tripod's interest, yes it has one too, is to hold the camera steady so it can record. The technology and availabilities of a tripod allow the action of steadying a camera to move from a person to a thing. The tripod makes it possible for Sari to film the interview without me there.

Getting back to the task of building an understanding of the architecture of DNA, the hands move between acting as an intermediary and a mediator. Sakina lifts two fingers vertically to represent strands of DNA. Here the gestured object is an intermediary. It transports the idea from an abstraction residing in Sakina to a public expression as a physical model made by the hands.

Latour talks about the disruptions that uncover traces. When there is a break in an anticipated process, associations are revealed. And when traces of associations operating in a network are revealed, the researcher can investigate. A disruption in the process of

transporting information happens in the Sakina-Sari conversation. One of these disruptions is marked by Sari's incorrect pick up of the hands as DNA. Sari fails to show the anti-parallelism when she reproduces the DNA gesture. Here the hands, previously acting as intermediary to transport information, become mediator. They work to transform Sari's incomplete conception of DNA to a clearer understanding of the idea. When Sari picks up the gesture incorrectly, it starts an activity of disassembling old conceptions and re-assembling new ones. The hands help do this. Sakina once again demonstrates the anti-parallelism of the strands. Sari then repairs her gestured model and flips one hand over to mirror Sakina's model (see Figure 2.3).



Figure 2.3. Gestures and the body as intermediaries and mediators

It is important to acknowledge that the hands are not the only tools used to create an understanding. It is their participation in a series of associations of representation that move the interest (the interest of understanding DNA crystallization) forward. A few turns later, Sakina moves the model of the DNA from her hands to a drawing. The representation of the structure of DNA moves through a relay of associations. It starts as an idea embodied by the expert. In the process of explanation it moves from idea through language, to the hands, and then over to paper and pencil. This is a network in action!

An aspect of the idea of ANT is the role of technology in the making of associations (the pen and paper is an obvious example of technology.) Technology refers to more than mechanical machinery or systemized process that contribute to the accomplishment of a task.. The word originally comes from the Greek words *techne* and *logos*. *Techne* means, skill, craft, and the manner in which things are put together in order to achieve a gain. *Logos* initially referred broadly to the systems and orders of representations and ideas. We can think of technology in a generic sense as to order and transform matter, energy, and information to realize certain valued ends. In this transforming, we use means such as language, tools, devices, systems, methods, and procedures.

With this in mind, the hands, the body and physicalized actions certainly act as technology. They are tools that are part of the network system and they participate in assembling associations to achieve an end. But if hands are technology, they are a very unique technology. They do not exist outside the human body, separate from the human actor. Hands can sometimes seemingly disassociate themselves from the body when we use them to stand in for things. We see this in the examples when gestures become the DNA. But they are never independent actors or things because they are never detached from the person. That is, in order to understand the complexities of gestures and body action in the network, we need to focus in to gain a workable conception of the body. Not only is it helpful to think of the body as something that learns to be affected. I also propose that we think of the body as a micro network. Rather than treating the body as a singular and separate unit, we can treat it as a dynamic system where associations are assembled, where many modalities and lived experiences act as instruments and actors to

help move along the act of assembling meaning in social activity. How might we chart out the body as a thriving, rich micro-network? Where are the intermediaries, the mediators and so on? This seems like a worthy exercise.

As the conversation comes to a close Mr. P. reminds me again that my work and his work is situated in teaching and learning. He smiles at me and says, “Did you learn anything in our interaction?” His tone of his voice punches as he says “interaction”. At the same time his right hand creates a circular path between him and me. His comment reminds me that learning is an interactional process. It is dynamically constructed through actions and inter-relationships among resources. As he leaves, he tosses an article on the table and says, “I think you’ll like this”.

In Goodwin’s article “Action and embodiment within situated human interaction” (2000), he takes these ideas to a place where a theory of the body for teaching and learning can bloom. He adds to them action. He shows that the construction of action within situated interaction is accomplished through the unfolding and ongoing re-arrangements of resources. Achievement of a goal is accomplished through the process of activity. This process of activity involves the blending, re-shifting, adaptation, appearance and re-appearance of all the resources in the dynamic system. The body not only serves as one of these resources, but also as an active coordinator for arranging resources to achieve a desired conclusion. So Sakina’s shift of her posturing to position the depiction of DNA made by her hands in the sightline of her recipient becomes a public display performed in the body, that in turn, engenders an action of Sari gazing to the depiction. Together this coordination for organizing action happens with the body

and is in service of the interests of the participants – the interest for Sakina is to get her recipient to a level of understanding.

Forming a Conception of the Body for Examining Interactive Explanations

To wrap up, teaching and learning is a complex enterprise where the organization of communication media affects the kinds of things the participants can learn. In the science community, as Latour has pointed out (Latour, 1987), the distribution of cognitive activity within social networks and between people and inscriptions accounts for much of the work that gets done in the science community. We see that from just the short bit of data showing science learning in action that I explored here, the hands and body are involved in the process. In the following analyses, I frame my investigation around ideas built out of the concept of the body as a resources of disciplining perception. The hands and body in action are (1) capable of construing concrete concepts, (2) a prominent resource and mode in a distributed cognitive system, (3) a micro network that learns to be affected, and (4) an instrument that works in collaboration to make associations and connections. This conception of the body offers opportunities for explaining the body's role in the process disciplining perception in science teaching and learning that, in turn contributes to innovative participation in the field.

The next chapter offers a review of the literature of the study of gestures.

Together with the established conception of the body I develop of frame for examining the data.

CHAPTER 3

**GESTURAL AND BODILY ACTIVITY FOR TEACHING AND LEARNING:
REVIEWING THE LITERATURE**

Introduction: Framing Gestures

Following I give a very brief mapping of the study of gestures and how such studies of gestures have trickled into investigations of teaching and learning. Such a review not only offers a background for which to understand what has been attended to thus far when a focus of gesture use is directed to teaching and learning, but also identifies questions and issues left open, giving way for the construction of new questions and new approaches to research that will effectively advance an inquiry of gestures into the field of educational research and the Learning Sciences.

The overarching interest of this dissertation is in how knowledge is shared and produced in interaction. I see learning as an interactional process that is dynamically constructed through actions and inter-relationships among resources (Hutchins, 1995; Stevens, 1999, Stevens & Hall, 1998; Williams, in press). These resources include participants, settings, multiple modalities, objects and sequences of activities that work together to discipline a perception for advancing understanding. It is because of this view that I am able to treat gesture as one of the multiple resources in the active and collaborative enterprise of teaching and learning. The review of literature aims to uncover empirical perspectives on gestures use in order to support the study of teaching and learning as a multimodal, embodied enterprise.

As the study of gestures spawns out of many disciplines, the field of gesture studies is populated with proponents attending to different aspects of gestures. In a discussion with a prominent researcher of gestures, she, giving notice to the multiple views that surround gestures as a focus of study, said, “ I work in one corner of the gesture study world. There are certainly many others.” My aim with this dissertation is to bring some of the ideas out of their own corners and in a shared space as educational research turns to the study of the hands and the body to better understand teaching in learning.

Conversing Across Multiple Views: Inside the Head and Within the World

Interest in gesture use spans across multiple social and scientific disciplines that include cognitive psychology, linguistics and communications, anthropology, sociology and philosophy. Studies interested in how the body relates to thinking and cognition can also be found in the field of neuroscience. For the particular interests of this study, I will concentrate mostly, although not exclusively, on how such investigations in the role of gestures and bodily activity have and might influence studies shaped by an interest in teaching and learning. I bound this review most particularly to literature on gestures from two mutually interdependent fields of inquiry. One takes a, more or less, ontological view and is born out of cognitive psychology and psycholinguistics. The other highlights the communicative role of gestures and develops out of the idea of interaction and social-activity.

The cognitive psychological perspectives frame gesture use as a way to understand mental processes. Gesture as social activity focuses on gestures as

communicative agents employed in and for interaction. I bound the review to these perspectives in particular because my question is trying to uncover how gesturing and bodily activity, such as posturing and gaze, support learning of specific concepts explained and negotiated in face-to-face interactions. I also focus intently on these two perspectives because they are the ones engaged most when discussing teaching and learning. My attention to these two views is not to say that investigations also need not consider other views. Other views should, in fact, eventually, be elicited for the study of teaching and learning as a comprehensive understanding of the enterprise of knowledge building requires an extensive overlap of multiple and diverse perspectives. For now, however, I begin this overlaying of perspectives by first engaging these two perspectives and encourage that further discussions ensue.

Although many players from the cognitive science/psycholinguistic perspective and the communication-as-interaction perspective participate in this conversation, those most dominant in this discussion are those who have most clearly set the stage for work currently done and currently to come in the field of gesture studies as it relates to teaching and learning. It is these representatives' voices that I bring into, metaphorically speaking, a round table discussion that aims to reveal what each perspective offers as gesture studies move into research of teaching and learning. On one end of the discussion table sit thinkers best representing the psychological orientation for gesture studies. These include David McNeill and Susan Goldin-Meadow. Across from them are those who have built upon the situated/communicative argument. This includes Adam Kendon, Jürgen Streeck, and Chuck Goodwin. Filling up the other seats at the table are those who queue up in line with these thinkers or fall somewhere in between both these

perspectives. At times in this conversation the ideas align, other times they complement, and sometimes ideas completely collide. In the end I will have identified key points across the perspectives, located potential problems, and highlighted those unexplored gaps that have helped shape this dissertation.

The first guests to arrive for this table discussion are David McNeill and Susan Goldin-Meadow. They sit comfortably at their end of the table where leaking snippets of private conversation push out phrases like “image schema,” and “gestures as windows into the mind.” The study of gestures for this end is framed by a cognitive psychological view of thought production and its relationship to speech. Gestures are seen as outward reflections of individual internal mental activity. Gestures, thus, make internal thought visible. For perspectives included those of McNeill and Goldin-Meadow, the activity of gesturing not only reveals thought, but it also fuels and propels thought, moving it from abstractions to concrete language. Second to arrive are Adam Kendon, Jürgen Streeck, and Chuck Goodwin. These guests locate gestures as participants in the entire enterprise of social activity. Gestures are called upon to do more than just reflect inner thought. They also communicate ideas, construct ideas, and organize activity in the moment of human interaction.

Although all the guests have the common focus of the study of gesture, they all come to the table with fundamental differences. What is generally the same includes the ideas that gestures (1) are elements of communication, (2) participate in knowledge production, and (3) act as mechanisms to organize conversation. How gestures do this and for what purpose is the point where the theories spin in alternative directions. As one view is predominantly mentalistic, the other is significantly social. The differing angles

not only reflect different views on gestures, but also, more strikingly, concede to notably varied perspectives on the nature of knowledge. For one group knowledge is largely individually achieved. For the other it is socially dependent.

A cognitive psychological view. I will begin with a review of literature that examines gestures in relation to thinking, most specifically gestures in relationship to thinking for speaking. These views are most influenced and driven by the confluences of the disciplines of linguistics and psychology. In short, the view puts to rest the longstanding view that language and gestures are two distinctly separate modes of information (Freyereisen, 1987) and thus suggests that “far from being ‘beside’ language, gesture is actively part of language” (McNeill 1986 p. 4). A steady stream of research (e.g. Kendon, 2000; McNeill, 1986, 1987, 1992; 1992; Tuite, 1993) now strongly supports that gestures and speech share a single psychological origin. I give attention to this view because much of the research on gestures in teaching and learning is build off this dominant perspective. Whether responding research aims to support, expand or refute the ideas present in this view, the notion that gestures are related to mental, individualist thought processes is ever present in studies and discussions. Following I present some significant contributions to for understanding the role of gestures that are emanate from the field of cognitive psychology.

Speech-gesture partnership: A psychological view. McNeill pioneers the speech-gesture partnership and its psychological origins that have come to frame the cognitive psychological perspective of studies of gestures. McNeill’s interests are primarily in the formation of language or “thinking for speaking” as an internal mental activity. Gestures for him are co-produced with speech, partnered with speech and are supportive of speech.

Gesture and speech work together by representing two sides of the cognitive coin. Gestures are the external manifestation of internal imagistic thoughts and schemas, while language is the external conclusion of internal categorical and linguistic thinking (McNeill, 1992, 2005). This speech-gesture synchronization forms meaningful combinations that reflect full thought units. For example, a speaker, explaining a cartoon scene, raises her hand upward to mean that a character in a story is climbing up. The rising hand expresses upwardness. The speech accompanying the gesture also expresses movement upward as the maker utters “and he climbs up the pipe”. Each element, the gesture and speech, thus manufactures thought. In this case both manufacture the same thought.

The gesture-speech liaison is also reflected through a temporal relationship. The specific phase of the gesture depicting upwardness coincides with the semantically most congruent parts of the utterance (“up”). This temporal confluence of speech and gesture suggests, for McNeill and others, that the speaker’s thinking is produced in terms of a combination of imagery (expressed outwardly in gestures) and linguistic categorical content (expressed in speech). It is important to note that the contents of the gesture and the synchronized speech need not be identical, as they are in this example. Each component can express different parts of the holistic content. For instance, a fast moving gesture may indicate that the speaker also has an imagistic schema that the climbing up was fast (the term often used to define related but not identical meanings expressed in the speech/gesture partnership is “co-expressive”).

In summary, for those studying thought production as an individual, mental activity, by looking at the speech and the gesture jointly, researchers are able to infer

more characteristics of the underlying idea unit the speaker is working with (this may not be obvious from the talk alone). This idea has grounded gestures as significant tools for revealing, as well as for motoring, human thinking.

The growth-point. McNeill has developed the concept of the “growth point” for analyzing gesture use in relationship to individual thought processing and language production. The growth point is a way to explain the image-word connection as a playground for developing thought for language. The growth point (GP) is an analytic unit combining cognition of images with linguistic categorical content. The beginning of the growth point is marked by a speaker’s minimal idea unit, usually only an imagistic schema and often outwardly expressed in gestures unaccompanied by speech. From here the thought develops toward a full verbal utterance with gesture. The thought process is then a combination of image schema and word that begins as a loose, rough, and unstable formation in the individual’s mind and works toward an articulated thought expressed in speech. The journey from growth point to clearly articulated thought reveals a process for thinking that moves abstractions into concrete units of information for the speaker, further expressing the interdependent relationship between gestures, talk, and thought production.

Studying “gesticulation” in narrative recalls. As McNeill escorts the study of gestures into the field of cognitive psychology, it is essential to examine his work as the foundation for further research. Research conducted by McNeill and colleagues looks most specifically at, what he coins, gesticulation. On a continuum of gesture classification, which McNeill has deemed the “Kendon Continuum” (McNeill, 2005) gesticulation falls on the end of the range that considers gestures as hand/arm movements

that are spontaneously and unwittingly produced in tandem with speech. (On the other end of the continuum are highly conventionalized hand gestures such that make up sign language). Gesticulations are improvised gestures that are speech-synchronized and created online by speakers at the moment of speaking. McNeill examines these ad hoc gesticulations in narrative re-tellings. His earlier studies take place in a lab setting where a participant gives an account of a previous viewed film clip, most often cartoons. The explanations tend to be narrative. Much of the activity is a translation of visual images into speech. For instance, a participant is asked to explain the cartoon scene, as referenced above, where he views a cat crawling up a drainpipe. Studies reveal the symbiotic relation of thought to language in the process of formulating individual cognition as evident through gesture use. To emphasize that ad hoc gestures support thought and are not simply and only a display for the recipient, McNeill also positions the re-teller out of sight from the hearer, behind a screen. Speakers continue to produce gestures in partnership with their speech, thus supporting the idea that gestures are used by the individual to move thought into language.

McNeill's work is significant to those interested in education and teaching and learning as it sets into motion the idea that gestures do participate in cognition. He lays out a way of looking at how this happens and gives us a kind of language to talk about gesture use and cognition. He shows that gestures, used as inferences about speakers' mental representations, can reveal a great deal about an individual's production of knowledge thus providing the field of cognitive psychology and educational research an insight into people's thinking strategies (McNeill 1987, 1992).

A developmental psychological view. The question that then comes off the heels of McNeill's legacy is if gestures participate in cognition and by doing so reveal inner cognitive processes, what more can they reveal about how we think? One of the key researchers to attend to this question is Susan Goldin-Meadow. Ushering the study of gestures directly into teaching and learning, she, as well as her colleagues, takes a developmental view on what the gesture-speech relationship reveals about how we come to thinking.

This work revolves and evolves around three main premises. First, cognition is predominantly a mentalistic act that is played out in the individual's mind. Second, thought representations, whether imagistic or sensory, need to advance to language. Thirdly, gestures act as the thread, the connector, and the avenue that transports abstract and imagistic thought to language. Gesture, thus, gives auxiliary support to cognition. It is this role of gestures as intermediary agents between developing thought and complete thought that has received the most attention in terms of teaching and learning, and contributed how research in teaching and learning is framed. It has brought forth the conception that in this transitional knowledge stage thought is unstable. This instability is made recognizable through the gesture-speech relationship. Examining these outward representations of inward thought becomes useful for understanding where learners are and defining how to proceed with a kind of instruction to stabilize knowledge and understanding. Gestures in partnership with speech, then, become a marker of a readiness to learn. This is further developed in the idea of gesture and speech match and mismatch.

The “match” and the “mismatch”. One of the main contributions to gesture studies in terms of teaching and learning comes in the form of the close examination of the continuity and discontinuity of an individual’s gesture production with and against verbal utterances, revealing a learner’s trajectory of knowledge development. Goldin-Meadow (2003) defines the (mis)alignment of gesture to speech as being either a gesture-speech match or a gesture-speech mismatch. A gesture-speech match is when gesture and speech reveal the same information. A gesture-speech mismatch is when each reveal different information. Studies suggest that a gesture-speech mismatch produced by the learner in the process of figuring something out can signal incomplete understanding (Goldin-Meadow, 1997, 2003). This can show that knowledge is unstable (McNeill 1992, Goldin-Meadow, 2003; Goldin-Meadow, 2004) and that the learner may be in a position of transitioning ideas into full understanding.

Studies of mismatch come out of an original experiment (Church & Goldin-Meadow, 1986, 1997) in which researchers studied how children explained their solutions to Piagetian conservation problems. They observed that some children in the process of explanation gave erroneous information verbally but gestural production indicated they understood more fully than what their words reported. For example, a child explaining what happens to volume of liquid when poured from a tall, thin container to a wide, shallow one gives verbal information that the content becomes less. The gestures, on the other hand, demonstrate the difference in width and height among containers. In a case such as this, Goldin-Meadow argues that the child has an understanding because the gesture production reveals a conception that the features of the containers governed the change in the liquid’s level.

This suggests that the learner is engaging in more mental processes than the language portrays. The gestures convey substantive information and, as such, provide insight into speaker's mental representations. It shows that a student's knowledge on the subject is neither completely out of the ballpark nor a clean home run. These findings contribute to an understanding of thinking by suggesting that knowledge develops in a process. It moves from no connections to basic ideas, to loose connections, to complete connections. Gestures help in getting to the conclusion of this development by holding bits of the knowledge until the puzzle gets completed.

This idea of a learners' mismatch signaling transitional learning begged the question if these "mismatchers" would more readily respond to instruction than those who did not display such mismatches. Further studies conducted by Goldin-Meadow and colleagues show that this is, in fact, so (Goldin-Meadow, 2003). The mismatch not only shows a transition of knowledge but a readiness for successful learning.

As this view primarily is interested in the use of gestures for thought development, it also considers how performed gestures act as means for relaying information. Later development of this research turns to the instructor and examines if teachers are able to use students' performed gestures as evaluation for student learning. An experimental study of one-on-one tutoring suggested that teachers often do use learner's gestures, among other signs, to redirect instruction (Wagner et al., 2003). Continued studies also show that teachers use gestures as instructional tools (Alibali & Nathan, 2005; Goldin-Meadow et al., 1999; Valenzeno, Alibali, & Klatzky, 2003). Teachers often employ two different correct strategies for problem solving, one in words

and the other in the hands. Studies show that students attend to both these lines of information (Goldin-Meadow, Singer, 2005).

Gestures as an outward demonstration of internal mental processes are, by their nature, witnessable. Inconsequentially this makes thinking visible to participants involved in the discourse. In this sense, a by-product of gestures as reflections on thinking are that they also act as communicative tools by showing others what is going on in the speaker's thoughts. For instance a circulating figure at the point of stops and starts of speech may suggest to the hearer that the speaker does not have the word for the mental representations he is trying to share. The gestures as first internal reflections can, simply by being visible to the hearer, communicate to the hearer the momentary instability of the process of the mental image moving to a linguistic manifestation and thus result in the hearer offering up suggestions. This vein of research considers the communicative aspects of gestures as a beneficial side effect of individual thought production but being communicative is not the primary function such gesture production serves.

An “Embodied Cognition” view. Another view worth reviewing falls under cognitive science under the banner of “Embodied Cognition”. Work from the field of Embodied Cognition has highlighted the role of certain perceptual experiences, particularly motor actions, in individual conceptual development. It helps answer the questions, for instance, about how making gestural artifacts supports conceptual understanding. Embodied Cognition, as defined from the psychological view, is still married to an ontological conception of cognition. Cognition is built on the premise that thinking is an individual mental act.

Instead of emphasizing formal operations on abstract symbols, this approach in cognitive science considers the relationship of the body to thinking by emphasizing the sensory motor function for perception as it is experienced within the body and is deciphered in the mind (Alibali & Hostetter, 2008; Kita, 2000). It is argued that the knowledge itself must be deeply tied to the body (e.g. Lakoff, & Johnson, 1999; Lakoff, G. & Núñez, R. (2000; Latour, 2004; Núñez, 1999). Explanations of how gestures reflect embodied knowledge consider gesture production as a motor process that is triggered by activation of perception and action that coordinates language production and mental imagery.

Hostetter and Alibali call this “grounded simulated action” (Hostetter & Alibali, 2008). As much work focuses on abstract visual images as translated into gestures, this development expands to include motor perception simulation. McNeill’s subjects give an account of action that is visually perceived, such as a cat climbing up a drainpipe. But gestures can also develop out of the producer’s action or simulation of action from a sensorimotor recall. Hostetter and Alibali, using McNeill’s data of a viewer explaining a cartoon, observes a child re-telling the section of a cartoon where the character “climbs up a drain-pipe”. The child in explaining “going up” climbs up the chair as if he were the character and the chair were the drainpipe.

This work is promising as it considers the body’s enacted experience as a significant resource for understanding. It, however, falls short for my analysis of collected data in that the view does not step outside the fundamental premise framed by cognitive science – that cognition is conclusively an individual, mental act. Although it does consider the body as a resource for holding information, the pathway for

understanding this information is ultimately through the mind. Gestures are still positioned as outward expressions of an individual's mental images. Although this view considers that some knowledge can reside in the body, it assumes that knowledge in the body is inevitably linked to cognitive processes in the individual mind. I want to further consider that the body can be an independent resource for thinking and understanding that couples with mental activity rather than being subordinate to it. I also want to further consider that thinking happens not just in the mind but is also developed in our experiences in and with the world.

A socio-cultural view. The ontological view of cognition offers up some valuable perspectives for pursuing inquiry on the role of the gestures in teaching and learning as in interactive process. Gestures are connected to thought, reflecting it as well as driving it. Gestures give us insight into thinking, as they are outward expressions of internal thought. People recognize gestures as mechanisms for the mentalistic organization of cognition. And people use gestures to scaffold other's understanding (e.g. Alibali, & Nathan, M, 2005; Valenza, Alibali, & Klatzky, 2003).

One setback to proceeding forward into research on teaching and learning with only this view is that it is built out of a traditional cognitive science approach to studying thinking that holds that it is a computational process happening primarily inside the individual mind. This limits understanding by confining the unit of analysis to the person. This seems especially confining as perspectives on teaching and learning are moving toward embracing the idea of teaching and learning as a situated practice that includes the external environment as offering equally participating resources for thought construction that go beyond a gesture-speech relationship. We can, for instance, turn to a growing

body of literature on ‘situated cognition’ and ‘cognition in context’ (e.g., Lave & Wenger, 1991; Hall, Stevens, Torralba, 2002; Hutchins & Palen, 1998; Hutchins, 1995; Stevens and Hall, 1998) that offers a complementary view to the idea that cognition is only an “abstract”, in-the-head process. These theories urge us to think about cognition as phenomenological and intrinsically taking place in learners’ moment to moment interactions with other resources, such as objects and people, in their environment (Goodwin, 2000; Hall, Stevens & Torralba, 2002; Stevens, 1999, Stevens & Hall, 1998; Varela, Thompson, & Rosch, 1991).

In conceiving of the educational project as a social, cultural activity rather than solely as an individual phenomenon, educators and researchers are beginning to consider learning and communication on the level of the group or class as well as on the level of the individual (a level of analysis paralleled in linguistics by the later development of sociolinguistics or cultural studies of language). As a result, researchers have brought this wider sociocultural focus to the development of gesture studies to understand how learning and teaching happens in school settings (Abrahamson, 2003; Alibali & Nathan, 2005, 2007; Hostetter, Bieda, Alibali, Nathan & Kluth, 2006; Hostetter & Alibali, 2007; Noble, DiMattia, Nemirovsky & Barros, 2006; Reynolds & Reeve, 2002; Roth & Lawless, 2002; Roth & Welzel, 2001; Valenzeno, Alibali & Klatzky, 2003) as well as out of school settings (Ochs, Jacoby & Gonzales, 1994, Goodwin, 2000, 2003; Goodwin & Goodwin, 1987; Hindmarsh & Heath, 2000; Stevens, 1999; Stevens & Hall, 1998). I will now move my review to such studies that take a more praxiological view of gesture.

Gesture as situated action. As we turn our attention to the other side of the table, we need to be aware of a philosophical switch on teaching and learning that moves

thinking and thought outside of the mind and into the world. Take for instance an episode from Stevens and Hall (1998). A tutor, Bluma, is working with a learner, Adam, on understanding how to plot points on a Cartesian plane. Adam is working on a computer to translate grid points from looking at a graph. In the process of solving the problems, his gaze goes to the edges of the grid paper, a place where the information he needs is not available. Bluma, aware of where his body is looking, frames the critical area of the grid with her hands, directing Adam's attention to the area that will help him solve the problem. As a result of this integrated interaction across people, representations and the body, Adam comes to a realization. The authors show that, "These actions... will be the resources for further development of his perception in subsequent episodes" (p, 120).

This analysis of this episode demonstrates a switch in thinking about teaching and learning as happening in the world and across modalities. Adam's change in understanding was achieved not in the mind alone, but was an interactional construction that happened because of the participants' actions in and with the world. That action that grabs my interest is Adam's gaze to the edges of the chart, Bluma's recognition of his gaze, and her subsequent gestural action to redirect his gaze. I now turn to researchers whose focus of study are these such moments of gesturing in the world to communicate and direct new understandings.

In this "corner" of gesture studies, gestures are viewed as situated action (e.g. Becvar et al. 2005; Chartrand et al. 1999; Crowder, 1996; Enfield, 2009; Goodwin, 1986, 2000a, 2000b, 2003; Hutchins, 2005; Hutchins & Palen, 1997; Kendon, 1990; 2004; Koschmann et al 2002; LeBaron et al. 2000; Nemirovsky & Tierney, 1992; Ochs et al.

1996; Reynolds & Reeves, 2002; Schegloff, 1998; Streeck, 1993, 1994, 2009; Williams, 2012). They offer analysis on gesture use that fits well with a view of learning depicted in the vignette above.

Adam Kendon, Jürgen Streeck and Chuck Goodwin take a praxiological approach to the study of gesture and locate the activity of gesture production in the embodied practice of human actors in socially constituted settings. Rather than only looking for mentalistic explanations for communicative processes and structure as stemming from individual psychology, this view turns away from the idea of mental spaces and individual competencies as primary for teaching and learning. It, instead, locates gesture production smack dab in the center of human action and interaction where participants are responsive to, dependent upon, and shaped by the materials, the activities, and the interests embedded in a particular real world setting.

Approach to research from this end is different. There are no laboratory settings, no control groups, and no hypotheses. Data is collected from real-world occurrences and closely observed to reveal what is happening for the participant in the moment-to-moment unfoldings of action and talk. There are some fundamental components of gestures in interaction generally shared by those representing this perspective. As set forth by McNeill, it is commonly accepted that gestures and language are inseparable. Gestures in use participate in shaping interaction as they can position participants according to the aims of the actors. Gestures, beyond setting up the interaction, also drive the action to a conclusion of a shared understanding. In terms of the production of knowledge in interaction, gestures can act as tangible objects of talk that can be used to develop, shape, and negotiate ideas and knowledge in interaction. In addition, gestures

are creatively partnered not only with speech, but also with other accessible materials in the interaction space; including things, context, and individual experiences. And finally, gestures are both a speaker and a recipient phenomenon.

The gesture-speech relationship as interactional. Adam Kendon, a long time contributor to the study of gestures for communicative action, builds his theory, much as McNeill does, on the premise that gesture and speech are two components of a single utterance (Kendon, 2004). There is a difference here though. The gesture-speech unit is not an expression of individual mental thought, but rather the on-going activity of communication. As a result, the speaker crafts the relationship between the gesture and the words in service of communication.

It is useful to look at Kendon's development of the speech-gesture partnership against McNeill's. Although both recognize that there is a necessary configuration between gesture and speech to make an utterance work, how this happens and what it achieves is quite different. For McNeill the gesture-speech relationship is made based on individual mental mechanics that deliver thought to language. For Kendon, it is not a result of mental machinery, per se, but an alignment that is achieved by the speaker for the sake of delivering information to a recipient. Kendon arrives at this conclusion that the speaker can control the structure of the gesture-speech unit of utterance as he looks at the speaker's timing of gesture production to speech production against the recipient's turns, both through words and gestures, in conversation. Kendon, like McNeill, notices that a gesture phrase can begin before a verbal phrase, but unlike McNeill, Kendon concludes the speaker intentionally makes the alignment of the critical aspects of both gesture and speech to achieve an effective expression for the hearer. Kendon thus sees the

gesture-speech symbiosis as “speaker achievement”. As the gesture-speech relationship is constructed by the speaker for the recipient, the gesturing activity becomes part of an on-going, conjoint, and dynamic pursuit involving all participants in action to achieve communication.

The idea of gesture activity being a speaker directed phenomenon done with the recipient in mind gets further developed by Jürgen Streeck. Gesture production becomes more than a speaker achievement. Streeck moves it into being a speaker-recipient partnership. In “Gesture as communication II: The audience as co-author” (1994), Streeck presents the idea that gestures are co-authored in the moment in the process of interaction. The recipient contributes to the construction of presented ideas in multiple ways. One way is that a recipient’s display of understanding or misunderstanding, whether verbal and/or gestural, informs the speaker on how he needs to adapt or build the speech and gesture partnership to move the conversation forward. Another way for recipient participation is marked by the pick up and use of the original gesture. The recipient can pick up the gesture and re-use it “as is” by mirroring the speaker’s gesture. The recipient can also modify and develop the gesture. Streeck contributes to a study of gestures by suggesting that the gesturing activity is an on going, back and forth exchange between active and responsive interlocutors in the joint pursuit of constructing understanding and achieving communication.

A good example of a speaker-recipient duet is found in the process of lexical recall where one participant is searching for a particular word. For the cognitivist, the individual’s gesture acts to fuel individual thought. For Streeck, the gesture acts to develop thought not through cognitive initiation but through social organization. The

speaker's gesture acts to enlist the recipient's support in the lexical recall. A recipient responds to a circling-hand or an open-palm, faced-up and takes it as an initiation to get in on the word search (Streeck,1994).

Gestures as coordinating agents. Image the setting of chemistry classroom. The blackboard is populated with varied markings such as diagrams, arrows, equations, and nomenclature. When the instructor speaks, she glides up and down the length of the blackboard, pointing to images, tracing over chalk markings, tapping her fingers over shapes and equations. Her arms move like an orchestra conductor as she coordinates the relations between multiple representations and students' attention to them. Betty's gestural activity does the work of coordinating the many bits and pieces of information into cohesive constructions of knowledge for the hearer.

Following I share perspectives on how gestures link up references and material representations available in the interactive space, and how gestures are used to coordinate participants' attention to the referents in the space (Goodwin, 2000; Stevens & Hall, 1998).

Gestures are part of "representational practices" (Hall & Stevens, 1995) that bring things, actions and ideas into the world. Goodwin refers to the representations that actions bring in to existence as "semiotic artifacts" (Goodwin, 2000). A semiotic artifact is a thing that holds meaning for the participants. Semiotic artifacts get effectively combined to make a complete statement through the use of actively coordinating gestures to link up the artifacts. For instance, the referent of a spoken "this" or "that" can get identified through a finger point (a deictic action) or an intentional gaze toward the thing it references. There are a handful of studies that look at gestures for the combining of

semiotic artifacts to make a complete statement for science and math learning (e.g. Alibali & Nathan, 2005; Crowder, 1996; Kress 2001; Lemke, 2000; Stevens & Hall, 1998; Wells, G. 2000;). These studies show that gesture use for coordinating representations is present in the classroom.

Gesturing orients mutual attention. It is not enough for the speaker to combine these resources effectively. The speaker also needs to do the work of making sure to orient the participant to the resources being used; the speaker needs to make sure he gets the recipient to see these actions (Streeck, 1993, 1994, 2009; Goodwin, 2000a, 2003). A speaker may position the body, adapt their own body in the sight line of the recipient, or use another resource such as speech to direct the recipient to information that is needed to achieve the communicative goal. So, as Goodwin reveals in his study of girls playing hopscotch, if one speaker wants to use an outspread hand as an artifact to emphasize the number 5 space on the hopscotch grid, she also needs to perform the gesture in the recipient's sight line. If the speaker wants to use the five-space on the hopscotch grid as a semiotic resource, she again needs to direct the recipient's eyes to it. A gaze shift to the artifact, a stomping of the foot on the square, or a finger point to the square are such bodily actions that coordinate the recipient's attention where the speaker wants it to be. In order for the task to be achieved the recipient also needs to respond to the request of the speaker to take focus to a particular action or artifact. Thus public orientation becomes an on-going bid and a multi-party interactional achievement.

Gestures for coordinating attention are often overlooked as critical aspects of whether gesture use is successful or not in teaching and learning arrangements. Some studies suggest that the increase in teacher's gesture use correlates with better learning

(Alibali & Nathan, 2005). A speaker may do a very good job of linking representations through gestures but if the speaker fails to coordinate the recipients' attention; the gesture as a resource for coordinating information may not be attended.

Gesturing for “Disciplining Perception”. Another use of gestures for knowledge building, already touched up earlier, is the use of gestures with other coordinated modalities to develop shared discipline-based understanding (Stevens, 1999; Stevens & Hall, 1998). Discussed briefly earlier, this becomes an important point to take to heart when adopting and adapting the study of gestures for the study of teaching and learning in interaction. As teaching and learning is an activity that brings a novice into a community of disciplined knowledge, understanding how gestures (as one of the many modalities present) participates in achieving this is critical. The study (Stevens & Hall, 1998) shows that the act of linking up parts through the use of the body provides new members an opportunity to weave together parts to develop the kind of perceptual tools needed in a specific discipline through the accumulation of representations. As understanding can be developed through a movement across representations (Hutchins, 1995), gestures can effectively direct and coordinate a learner's attentional orientation across multiple representations that make up the discipline and guide the participants to the same perceptual page, directing new learners through the use of the body closer to discipline understanding.

Gestures as external artifacts. Gesturing hands can create tangible artifacts. They can bring non-present objects or actions into being. For example, one flat-palmed hand gliding over another in the horizontal plane brings subduction of tectonic plates into the talk (Singer, Radinsky & Goldman, 2008). These gestures, often referred to as

representational gestures, can animate talk by offering a visual accompaniment. They can also act as the central object of talk (Becvar et al., 2005; Goodwin, 2000). I now turn to literature that discuss gestures that represent things and actions.

Much of expert scientific talk occurs in the presence of an object of talk such as physical models and graphs (Kress et al., 2001). But when an object is not available or when the available objects fall short, speakers employ gestures to stand in (Becvar, et al., 2005; Ochs, Gonzales & Jacoby 1996). Hands can become the artifact of talk by becoming models or representation of concepts or objects in talk, such as molecules or DNA structures. These gestured representations become very present cognitive artifacts for formulating thinking. Such representational artifacts created by the hands and acted upon by the participants can work as “communicable instantiations” (Becvar et al., 2005). The “communicable instantiations” can make features present that cannot be as successfully conveyed in other modalities alone. For instance, the moving hands as a three-dimensional representation of molecules can show the dynamic process of bonding to another molecule. These portable and transferable representations can also easily be picked up and reshaped by others in the process of conversation. The gesturing hands thus support knowledge building because they can act as the material for building flexible, easily called upon, and transferable artifacts of talk.

Gestures as grounding elements. Studies also suggest that gestures may be used as, to use Hutchins’ term, “material anchors” (Hutchins, 2005). Representation gestures as material anchors can ground the concept in play by enacting and representing it in a gesture as a “thing”. For instance, interlaced hands come to represent a particular molecular construction. These ideas materialized through gestures can move from

speaker to speaker (Becvar, Hollan & Hutchins, 2009; Hutchins & Numera, 2011; Williams 2009). The gestures as artifact are transportable, transferable, and manipulatable. And as the gestures move from participant to participant they get worked on. They develop, get changed and may take on new meaning. Ideas, thus, are circulated through the “uptake” of the gestured object and expanded upon through the collective re-designing of the gestured object or idea in the process of talk (Becvar et al., 2009). This is particularly of interest in science talk as science talk takes place among multiple representations such as graphs and models (Kress et al., 2001). The hands are instantly available to create kinetic, malleable models that can, as the ideas evolve in collaboration, be altered and adapted, moment-by-moment to align, complement, and enrich the developing theory.

Emerging Questions Across the Views

As discussed above, the study of gestures has developed out of multiple disciplines creating diverse perspectives for examining the role of gestures and the body across cognition, communication, and interaction. Each perspective individually offers valuable insight to apply to an investigation of how gestures and the body are used in interactive explanation. But fully Understanding the role of gestures in teaching and learning requires taking into account cognitive, communicative, and interactional perspectives. As blending these perspectives offers a greater spectrum for analysis, blending perspective also poses some contradictions that open up key questions that are reflected in the upcoming analysis that considers all views. Following, I attend to the emerging questions.

Gesture activity across Levels of knowing? The literature I discuss in the following section considers gesture activity across levels of knowledge and across contexts for knowing but poses some conflicting conclusions that invite further investigation. There is a handful of literature that considers gestures and the body in the exchange and development and communication of knowledge among experts in discourse (Becvar et al., 2009, Goodwin, 1996, Ochs et al.). The work collectively suggests that scientists, physicist, and chemists come to interpretation of subject matter through sensorimotor and symbolic re-enactments; and that expression and communication of subject matter is dependent on such semiotic tools as gestures as they work together with other signs in the “semiotic field” (Goodwin, 2000). Considering this work is important to understanding how gestures are used in thinking and learning in less expert environments where teaching and learning is the central activity as it gives us insight into what people at levels we aim to teach for do naturally. The gesture use discussed is not strictly ad hoc gesturing. Much of the focus is on intentionally built, representational gestures that are highlighted for the speaker and acted upon by members in the conversation. These gestures are used in the collaborative process of theory building among experts.

It seems a valuable pursuit to understand the relationship of gestures in learning by looking at gesture use across various learning arrangements made up of novices and experts. Gesture use seems to differ across differing levels of knowledge stages. One study examines (Reynolds & Reeves, 2001) students collaboratively attempting to solve a math problem. The knowledge level for both students is relatively the same. The study shows that these learners used gestures as cognitive amplifiers in their process. The

gestures stepped in where disciplined specific language was not yet mastered. Gestures as stand-ins for language not yet acquired at a base level of understanding allowed the task to move forward. Gestures here act not as representations of knowledge but rather as fillers where there is not yet an understanding.

In the referenced study by Stevens and Hall (1998) a tutor (Bluma) is working with a learner (Adam). Here the knowledge level is asymmetric. The gestures seem to serve a different function than they did for the learners in the above-mentioned study. Although learner's gestures may be used to substitute for talk not yet acquired, Stevens and Hall (1998) suggest that gestures in partnership with other modalities participate in the expert's task of training a learner to "see" like experts see in a discipline. They support a disciplining of perception. The body in coordination with talk and artifacts supports this learning by directing focus and linking material representations. Such actions as finger points, body shifts, gaze, and the physical coordination of objects with objects helps achieve this. Both these studies point to the multiple roles gestures can serve in teaching and learning and suggest that use may be shaped by the levels of knowing and goals that are present in any given learning situation.

Taking up gestures? There has been a flurry of recent work investigating gestural uptake in the same conversation. Much of this work is focused on spontaneous gestures and not depictions that are intentionally highlighted. This work suggests that interlocutors often repeat each other's non-verbal behaviors (Chartrand and Bargh, 1999; Bernieri & Rosenthal, 1991; Holler and Wilkin, 2011; Kimbara, 2006). Such findings suggest that the mere observation of another engaged in a physical act can trigger the same action from the perceiver. For instance, Chartrand and Bargh (1999) found that

participants were more likely to shake their foot or scratch their heads during a conversation if their confederate conversation partner did the same. It has been concluded that such uptake physical action demonstrates an interactional alignment. But the gestural uptakes in studies such as these are not consequential gestured depictions that are part and parcel of the talk at hand. They are idiosyncratic gestures that accompany talk. What about the uptake of the gesturing used to create relevant depictions for explanation? Participants in conversation may very well reproduce intentionally built gestural depictions to serve the interactional purpose of demonstrating alignment with the explainer. This is an open space for further inquiry.

A handful of studies concentrating on teaching and learning have shown that a recipient's gestural up-take and adaptations are more than just a demonstration of interactional alignment. The taking up of gestures can also serve, for instance, as mechanisms to display understanding and as resources to support meaning making processes (Koshmann and LeBaron 2002; LeBaron and Streeck 2000; Singer and Radinsky, 2010). Other studies have shown interlocutors take up and modify conversational gestures when talking about the same event or object and show how they develop jointly over time (Becvar et al., 2005; Tabensky, 2002; Kimbara 2006). Although this work begins the conversation on how gestures are received by recipient, there needs to be more investigation into the uptake of intentionally made gestural artifacts that are explicitly highlighted by the explainer for the recipient in teaching and learning interactions.

Gestural activity for achieving conceptual change? Goldin-Meadow and others show that gesture production supports a change in thinking as gestures act to off-load

cognitive work, and step in until understanding gets to clear language. Another view of gestures as supporting conceptual change shows that gestures offer valid evidence of understanding on par with verbal articulation.

A major issue in teaching and learning is determining if learners are actually learning. Standard tests that assess understanding through a verbal modality may not be giving us a full understanding of what learning is happening. Educators look for other signs for learner understanding in order to assess what knowledge is being picked up and what is being left behind. Koschmann and LeBaron (2002) suggest that gestures perform a role in demonstrating knowledge in the process of learner articulation. The authors take the stance that learner articulation happens in a two-step process. First there is the act of giving utterance or putting one's ideas into words. This is followed then by the action of joining and interlacing disconnected concepts and ideas. The study reveals how gestures as well as words can participate in the act of giving utterance - physical articulation counts as knowledge demonstration as well.

What this study adds to the cognitive psychological perspective that gestures make thought visible is that understanding is more than a passing up from one modality (the body through gesturing) to another (language articulation). It is rather a two-step process that integrates both. Gestures participate in the learner's combining and joining of bits and pieces of knowledge that exists in talk and in gestures to achieve understanding. It is important to note that the linking of ideas is not viewed here as mental activity like we see with the cognitive science view. Knowledge is achieved through an interactional activity. This idea of gestures as coordinators is much like what we see with the Stevens and Hall (1998) research. Here, however, the practice is shown

as possible support for conceptual change. Extending the idea of gestures use in the process of conceptual change seems to be an obvious development from what research has already been done in terms of gesture use as linking up bits and pieces of knowledge.

The Benefits of Looking at Gestures and the Body from Different Views

Views from diverse angles inevitably provide valuable insight to questions about what gestures do in the process of teaching and learning. In short a cognitive psychological view gives us an understanding of gestures in relationship to individual thought production. An embodied view opens the door to studies of the body in action. Studies done in a lab give us focused insight into specific mechanism associated with gesture production and cognition. Studies done in the context of school, work and other arrangements where teaching and learning happen reveal that gesture can be part of the context and interaction.

Adopting one view without the other gives us only part a picture. When we see learning as a mentalisitic phenomenon and gesture and language as outward displays of internal learning we seem to not be paying attention to the other parts of understanding. This inhibits the proliferation of new ideas on the subject. On the flip side, an interactionist view, the view with which I sit most comfortably, falls short as well. We sometimes fail to take in that a clean cognitive science perspective is also useful. We need both views. When we begin to consider the views together then we begin to weave a rich tapestry of possibilities for making meaning of what is happening when gestures are used in teaching and learning arrangements.

It is obvious that much too little work is taking place in the field of educational research and that ethnographic studies directly attending to gesture use in the classroom are far and few. Dominant research, although crossing over in research on teaching and learning, is happening in other disciplines such as cognitive psychology, sociology, and linguistics. Educational researchers do not currently have a central presence in this ongoing and developing conversation. It seems at this point in the evolution of gesture studies and educational research that there is the call for an effortful move to join valuable yet fragmented parts. This requires the crossing and interweaving of other disciplines and those who study them. I do not simply mean each perspective's cordial consideration of other perspectives. I propose an intense collaboration that leads to a re-conceptualization. One of the outcomes of this literature review is, just that – an inquiry that blends perspective to better understand what happens in teaching and learning to better inform new designs.

At a cursory glance there seems to be a cognitive perspective - interaction perspective divide. There can appear to be two extremes. But a closer look reveals that ideas are not contradictory but simply born out of very different premises on what knowledge is and how it is constructed. It is not as if the discussants in the conversation sit apart from another with beady eyes, scowling faces. I see them as not at all in intentional opposition. Rather they sit in discussion with a sense of intrigue and interest in what the other brings to the table. The more popular angle – cognitive psychology- is eager, I suspect, to look beyond its own legacy.

More recent work in cognitive psychology appears to be moving closer to the work that is happening there from the interactional and socially situated perspective. Take

for instance McNeill's discussion of material carriers and the role of context in his recent book. Material carriers have a lot in common with the semiotic artifacts that Goodwin discusses. The difference however is that material carriers come back to being mental schemas. It is the same with the idea of context. Context for McNeill is social-mental interface. Goldin-Meadow recent works also points to an overlapping of ideas across domain. Studies are moving out of the lab and into naturalistic settings where she considers the interaction between speakers. But once again, all falls back on computational view of information processing. All roads circle back to the individual mind.

On the other end, Streeck talks about thinking with the hands. "Ceiving" (Streeck, 2009) refers to a kind of hand activity that helps in the process of figuring things out. And although I do not see this with our interactional guests who embrace the theory of the social as the platform for cognition, a pure theory of situated cognition and socially constructed human activity gives little room to the study of the individual mind. So we need to re-conceptualize and consider the joint contributions and mutual constraints of both mental and social structures as we try to understand human teaching and learning in interaction.

These developments of the prior chapters have allowed me to construct a launching point for investigating the role of gestures in teaching and learning. I move forward, situated in the interest of how knowledge is shared and produced in interaction, and with the perspective that learning is an interactional performative process that is constructed through actions and inter-relationships among resources (Goodwin 2000; Hutchins, 1995; Stevens & Hall, 1998) that include the hands and body. I also take with

me into the analysis an investigative crossing of ideas originating in different corners of gesture studies with the aim to blend them in ways that best uncover the role of gestures in teaching and learning

Building off Stevens and Hall (1998; Stevens, 1999), I take the view that the activity of explanation in STEM fields is one process for “disciplining perception”. It is an event in which a person who knows more about one thing guides another who knows less towards characteristic practices and ways of thinking in a discipline. And in this process of disciplining perception, the hands and body are used as representational resources to communicate and think through ideas as well as moves to regulate the interaction. Beyond this, the interactive process of explanation and re-explanation becomes an opportunity to teach the body to be affected, an opportunity to discipline the body as a register for discipline information as experts share their gestural representational practices for depicting concepts in their field with non-experts, and non-experts take them up for their own re-articulation to another.

With all this in my suitcase, I embark on an empirical investigation to understand the functional role of gestures for the explanation and re-explanation, of complex STEM concepts in face-to-face arrangement between expert and non-experts, and those in between. My aim is that such an approach opens up further discussion about the complex role of gestures and the body and gives way to new designs for teaching and learning that blend research and make effective use of the body as natural, always present source for developing and communicating understanding.

CHAPTER 4

COLLECTING AND ANALYZING DATA

Introduction: A Qualitative Study of Gesturing in Interactive Explanations

The study engages a qualitative methodology that involves a sequential and constant comparative analysis (Glaser & Strauss, 1967; Strauss & Corbin, 1998) of interactive explanations and re-explanations in which I asked experts in STEM fields (Science, Technology, Engineering, Math) to explain a concept of their choice to a non-expert in face-to-face learning arrangements. The non-expert was then asked to re-explain the concept to a less knowledgeable other two days later. I facilitated this set up in order to be able to see how experts and non-experts make use of the body for explaining and understanding STEM concepts in interaction.

The overarching methodology for this study originates from microethnography, a set of techniques that focus on moment-to-moment bodily and situated activity. Microethnography techniques trace, among other things, talk, gesture, body posture, facial expression, inscriptions, tool use, gaze and timing (Erickson, 1996, 2006; Goodwin, 2003; Hall and Stevens, 1995; Strivers & Sidnell, 2005; Streeck & Mehus, 2004). This fine-grained, qualitative analysis of sequences of talk and action allowed for the close investigation of moment-to-moment, turn-by-turn, (turns in both talk and gestural production) interactional exchanges, giving detailed information about what is happening in a particular instance. (Derry et al., 2012; Erikson, 1995; Goodwin, 1993; Heath & Hindmarsh, 2002; Hutchins 1995; Jordon & Henderson 1995; Schegloff, 1987). I used videotaped recordings to examine the micro-behaviors of participants in face-to-

face, interactive explanation arrangements as a means to better analyze ways various resources such as the body are drafted into service as functional modalities for teaching and learning.

I am sensitive to the idea that micro-ethnographic analysis is most often applied to naturally occurring interactions and that by arranging the interactive explanation interviews between experts and non-experts and then the interactive re-explanation interviews between the non-experts and less knowledgeable participant, the data run the risk of appearing less natural and somewhat contrived. However, although interactions were arranged by bringing experts and non-experts together to discuss disciplined concepts of their choice, the interactions that unfolded in these interview settings developed naturally and spontaneously. It is these interactions that are the focus of this study and give rise to opportunity for answering questions about how the body participates in teaching and learning for STEM concepts in face-to-face interactions

Methods for Data Collection and Analysis

Collecting the data. The entire database consists of approximately 32 hours of videotaped conversations. Participants came from a pool of volunteers who responded to requests for participation distributed via e-mail to departments of a large university or who were recruited in a door-to-door process where interviews took place on the spot. The interactive explanations lasted between 30 and 60 minutes. The experts discussed topics of their choosing that they deemed as relevant concepts to their defined discipline and/or research. In a later iteration, the non-expert participants re-explained concepts to a confederate researcher who did not have the privileged of the original explanation.

Confederate researchers were aware of the project as a study on teaching and learning but were not informed of my interest in gestures. All interviews took place in experts' offices, labs, conference rooms or cafes near campus. Participants were not asked to gesture and were given no formal instructions on how to conduct the conversation. Experts were informed that their goal was to explain the concept to the non-expert in a way that it was understood well enough for the participant to re-explain it to another. The recorded interactions were logged and transcribed and the verbal and gestural techniques used to explain concepts were identified and analyzed.

Data collection happened in two phases. In the Phase One there are 18 conversations, totaling approximately 14 hours. Conversations include experts explaining a variety of topics. The expert participants shared a complex concept with one of two researchers, one being myself. The researcher as conversation partner prompted the discussion by asking the expert to explain a concept that was difficult to teach or that was critical to understanding the discipline.

Both researchers, myself and another researcher, participating in the Phase One of the interactive explanations had little to no experience with the sciences. (Neither had been formally trained in the disciplines). I limited our gestural practice as to not initiate new gestures but to only respond naturally, if necessary, to gestures that were explicitly highlighted for us as conversation participants. I made the choice to bound the interaction in this way because gesturing is a natural aspect of interaction (Schegloff, 1987), and to extinguish all gestural possibilities would deny the opportunity for exchanges to develop naturally.

As the task for experts-as-explainers was to make content understandable, the researcher-as-conversation-partner operated on the goal of gaining an understanding of content well enough to re-explain to another person. In some cases, depending on where the interactive explanation took place, participants had access to a white boards or chalkboards. Additional resources such as computers, inscriptions, notes, and books were available in interviews that took place in the expert's office. For all interviews, the researchers made a blank tablet of paper and a pen available before the interviews began, setting the resources in view of the expert participant. In 16 of 18 of the interviews, the expert used the paper and pen or whiteboard in at least one instance of an explanation.

Only one camera was used in the first three discussions. After a preliminary analysis revealed that information sketched on either paper or white board was not accurately captured, I employed a second hand-held camera. One camera was mounted on a tripod and captured both the expert and non-expert, with primary focus on the expert. The other camera captured what was written on paper or on chalkboards and white boards.

Phase One of data collection posed some limitations as it also raised interesting questions. One obvious limitation was the researcher as conversation partner. I questioned how much of the my interactional activity influenced the expert-explainer's gestural practices. After analyzing data from Phase One, I noticed that gestural practice in teaching and learning arrangements is clearly a conjoint activity, supporting previous studies that show that interaction is dependent upon a give and take exchange between interlocutors (Brassac et al. 2008; Goodwin, Stevens and Hall, 1998; Streeck, 2000). For instance in teaching and learning arrangements, an audible "OK", a head nod and a

questioning gaze cues a participant on how to continue to achieve the shared goal of explanation and understanding. Gestural uptake and acknowledgement of gestures produced does the same. The expert-explainers' gestural practices were, in part, shaped by the learner's interactional response. I then questioned whether by requiring the myself as researcher to not initiate new gestures and to confine their own gestures to those in response to the speaker that we were creating a false sense that gestural practices are directed and steered by the expert as explainer. These reflections guided me to alter the collection process.

Such questioning also sparked an interest in exploring not only what the expert-as-explainer was doing with gestures in explanation, but also what the learner was doing with the gestures in terms of understanding the concept and participating in the teaching and learning interaction.

New questions that came into view concerned how both recipients and speakers used and responded to gestural production. How do participants negotiate gestures as a modality for communicating ideas and "thinking out" ideas in interaction? Further more, if gestures are shared in the expert-explanation interaction, as I recognized in preliminary analysis of data from Phase One, are they carried over into the non-expert re-explanation? As a result of such emerging questions and concerns, I altered the study.

In Phase Two, the researcher-as-conversation-partner was replaced by a participant not associated with the research. The non-expert participants came from academic disciplines other than STEM. Participants were recruited via email from a large university pool. Participants included undergraduate students, graduate students and instructors at the university. Non-expert participants were asked to engage in

conversation with an expert. As with expert participants, these newly recruited non-expert participants were not asked to gesture so all analyzed gestures are naturally occurring. The non-expert participant's defined task was to try to understand the concept at hand as best as possible. They were told that they were to share what they learned in the expert-explanation conversation in a second conversation with a less knowledgeable other that did not have the privilege of conversation on the subject matter with the expert. Non-expert participants were instructed not to do any outside research on the topic in between the expert explanation and the re-explanation. Non-expert participants re-explained the topic of talk to a "confederate" two days later. Confederates came from a pool of researchers from the research center where I work. Confederates had various levels of knowledge about the subject of the study. Confederates were given the task of trying to understand the concept explained enough to re-explain it to another. This move gained me the opportunity to trace the gestural activity over time and across consecutive conversations from expert explanation to non-expert re-explanation.

I was also interested in seeing if gesture production changed across re-occurring opportunities for explanation. As a result of this interest, I requested that the experts participate in three to four explanations with different non-expert participants at each time. (Exploration of these phenomena is not part of this current inquiry).

Phase Two is made up of six experts-as-explainer participating in a total of 15 expert explanation conversations, comprising 11 hours of video data. There are a total of 15 re-explanations equaling approximately seven hours. (One of the interactive explanations was a triad. The two non-experts participating in the triad re-explained

individually on separate occasions.) It is the data from Phase Two that is the primary object of analysis although data from Phase One is also cited.

In Phase Two three cameras were available to capture the interaction in both the expert-explanation and the non-expert-re-explanation. One camera was mounted and focused on both participants. The second camera was mounted and focused directly on the non-expert as explainer. In some cases the third camera was used to capture only the drawing that participants made during the re-explanation. Cameras were filming before the defined discussion began and after the official conversation concluded. This was done to gain more opportunity into natural occurring conversations. The first four expert-explanations (the first two experts explaining to two different non-experts) took place in the offices of the experts. Such conversations were prone to mimic practices common to lectures as the non-expert sat and the expert presented in front of the white board. As my objective was to see how talk and action unfolds in interactive explanation, I changed the setting to encourage a different kind of arrangement between participants. Explanations moved to more neutral places, such as conference rooms where white boards and paper were available but not part of one's own familiar surrounding. I set up the interactive explanations by framing the conversation something akin to a "casual exchange at a dinner table". This simple framing altered roles enough to reduce the didactic teacher-learner orientation that was more dominant before the change. One conversation took place in a bar.

All non-expert interactive re-explanations took place in a designated conference room or lounge on campus. As in the expert explanation, three cameras were available. One focused on both participants. The second focused on the explainer, and the third

available to capture details of drawings and markings. As in Phase One, the cameras were rolling before and after the official conversation.

While interactive explanations were in session, I maintained a time index and field notes to address aspects that may not have been captured on videotape. Although the video recordings act as my main source of data, the field notes act to complement and explain what the videotape has not captured.

Analyzing the data. Data analysis follows the practice of grounded theory in which themes and concepts emerged inductively from data, and were further developed through subsequent analysis. Analysis began with a broad view of the data. I first investigated each of the videotapes looking for patterns in and across events. (Derry et al., 2012; Erikson, 1995; Goodwin, 1993; Heath & Hindmarsh, 2002; Hutchins 1995; Jordon & Henderson, 1995; Schegloff, 1987). Using *Inqscribe*, a computer program for transcribing video, I maintained a content log for each scene, which provided a time-index outline of the events in the video and marked gestural practices around talk and actions. The content log provided me with a sense of the corpus of data, facilitating the selection of scenes for further analysis. At first, I framed my viewing with the broad interest in how gestures and bodily activity participated in teaching and learning exchanges, as I remained expectant of unanticipated phenomena. Using grounded theory (Strauss and Corbin, 1998) as I watched I began to develop an interest in certain categories of practice, which I then noted. I became particularly interested in gestures that acted as depictions representing artifacts and actions. The phenomenon that emerged through the data and not fully represented in existing literature was the joint use of representational gestures. That is, gestures that are construed to stand in for an existing

thing or action on a thing to communicate ideas think through ideas and orient and direct the teaching and learning interaction. I refined my coding process to highlight moments of this kind of use of gestures.

I used *Inqscribe* notes to complete a log specifying the participants, the talk, and the gesture use captured on each videotape. I organized logs of each interview registering these activities and adding notes. I went back to the moments in the videotapes where participants used gestures to represent things and phenomenon and transcribed the talk and gestural practices surrounding these events. I devised a coding schema to categorize the gestural practices highlighting both the actions for creating the gestures and the functions gestures appeared to serve for all the participants. (Explained below).

I then compared gestures used to depict information in the original explanation to the gestures used to depict information in the re-explanation. I noted gestural practices in the re-explanation that corresponded, related to, or contradicted gestures use in the explanation. (1) I noted direct take up, derivatives, variation, and adaptations of gestures used in explanation. (2) I noted the interlocutors' attentional orientation to the gestures. (3) I also noted features of the gestural practices to help identify functions gestural activity may be serving for the participants in the interaction. (This is discussed in more detail below in "Terms and Definitions). I then set moments in an experts' explanation against the non-experts' re-explanation where gesture use carried over. I subjected these to sequential analysis.

To support analyses, I created a visual table from each scene. I pulled frames from the video that captured a gesture in use and aligned them in sequential order. I then added the talk in rows below the image and identified categories of gestural practices in

the row below that one. I set corresponding logs from the explanation and re-explanation side by side to compare similarities and differences in the gesturing across the expert as maker and the non-expert as maker in both the explanation and the re-explanations.

In the analyses to follow, I offer three levels for representing the talk and gestural activity. Level one provides a transcription of talk. I enumerate each speaker's turn and refer to each numbered turn as a "unit". The second level of representation provides a frame from the videotape recording. Talk accompanying the moment is included on the line below the visual frame. The talk that corresponds directly to the moment of action depicted in the frame is boxed. A written description of the bodily action appears below the line of talk. The third level is the use of written description in the paragraphs to follow the images to convey how events unfold and the relationships between actions in more detail. Although not a perfect re-representation of talk in action as the limitation of this process is that tables and charts do not adequately reflect the layers of activity that happen simultaneously in real time, the use of all three representational modes adequately captures what is happening in the events.

Terms and Definitions

In order to talk about knowledge and learning that engages multiple resources in interaction, I patch together theoretical ideas explained in Chapter 2. From cognitive psychology I take the idea that thinking can be a mentalistic act. From psychological and cognitive anthropology I expand the unit of analysis from the individual to encompass aspects of the world. I add the notion of knowledge and learning as products of social activity, and I treat gestures as part of the functional systems through which cognitive

outcomes are accomplished. From sociological studies of science, I adapt a way of talking about teaching and learning as organized networks assembled through associations of people things and ideas.

Defining terms. Following I outline the terms and definitions I use to help make sense of the data. I borrow from the above-mentioned traditions, employ and adapt existing terms and create new ones in an attempt to give appropriate language to a phenomenon that does not quite adhere to already established language. The result is not a complete language, but a supple language, none-the-less, that allows for a discussion of how the body participates in teaching and learning in interaction. I, of course, invite further development on language derived from this study.

These terms and definitions have developed out of a process of grounded theory. Terms first evolved during the preliminary passes of data and have since been refined in the process of deeper analysis.

Interactive explanations. “Interactive explanations” develops out of the idea of discipline perception. Disciplined perception is a term used (Stevens and Hall, 1998, Stevens, 1999) that refers to the multimodal activity participants employ in interaction when the more knowledgeable other is training less knowledgeable others how to “see” in order to participate in that community. Explanations are a genre of this activity. I engage the term “interactive explanations” to express the position that the explanation of concepts can be a dynamic exchange between people, the context, and the resources available and activated in a teaching and learning arrangement. “Interactive” refers to the back and forth exchange across people, things, and action that allows for the planning, crafting, and building of the explanation. Each turn in action and talk is based on and

updated from prior turns and actions involving all actors. As a result each actor and each turn influences the planning, the execution and the reception of the explanation, allowing for the unfolding of a progressive exchange that leads to joint achievement.

What counts as gestures? In this study, I define gestures to include not only the activity of the hands and arms, but also of the body and head. When I engage the term “gesture”, “gesturing” or “gestural activity,” it can refer to whole body action. This includes (1) hands and arms articulation, (2) body posturing and actions, (3) and gaze. Furthermore, throughout this analysis, the terms “gesture”, “gesturing” or “gestural activity,” are infused with the idea that gesturing is an activity that serves varied functions as shaped by the people, setting, and goals of the interaction.

In classical gesture studies “gestures”, or more specifically “gesticulation”, has been defined as improvised hands and arm movements that most often are speech-synchronized and created online by speakers at the moment of speaking (McNeill, 1992). I, however, consider gestures as also happening in the absence of talk.

It is also important to note that McNeill has created a well-used and valuable typology to talk about gestures as he divides gesticulation into such categories as iconics, metaphors, beats, and deictics. I choose, however, to steer away from these terms in the following analysis. One reason I make this choice is because these terms have come to be used in studies that focus primarily on gestures as “a form of cognitive expression” that are “used to access a speaker’s mental representations” (McNeill, 1997, p. 190). My perspective is that gestures are more than representational expressions of internal individual cognition. They are actions that happen in the world and between people. This brings me to another reason I steer from classical terms to define gestures. Terms

defining specification of gestures have, more or less, attended to the morphology of the hands rather than to the action they perform. I aim to employ a language that focuses attention on what gestures DO rather than what form they take (Kendon, 2004; Murphy, 2003).

“Depiction” vs. “Representation”. In this analysis, depiction is defined as the “action of the hands and body used to evoke elements of the world” (Streeck, 2009, p. 120). This study concentrates on gestural activity that invokes tangible objects and performable actions. Formerly such gestures might be classified as iconics (McNeill), illustrators (Feyerson, Ekman), or representations. I, however, following Streeck’s lead (Streeck, 2005, 2009), use the term “depiction” instead of the above terms. The word depiction is more than just a picture or illustration. Coming from the Latin “depingere”, it means to portray, but also to sketch out, describe, and imagine. In this analysis, depiction is used to emphasize gestural activity as an action that *evokes*, rather than simply re-represents, elements of the world. This definition emphasizes gestural depiction as an achievement that stimulates a perceptual and imaginative experience, either visual or sensory motoric, and brings a thing or action into existence.

I take a moment here to re-iterate that gesturing takes many forms in interaction. Gesturing can support, complement, replace, and re-iterate the talk. Gesturing can direct, refocus, and realign attention. It can coordinate other representations with one another. They can be coupled with other tangible resources in the space. And, as is the focus of this study, they can take on a representational role and depict things, actions and concepts. They can do one of these or all of these sequentially or simultaneously and interchangeably. It is, then, impossible to assign a unilateral nature to gesture activity as

it happens in everyday instances. That being said, the act of analysis asks us to break things into parts. The part I will be breaking off to examine in more detail here has to do with gesturing as representation, or more specifically gesturing for depiction. As the study emanates out of this focus, it is not to suggest that this is the more valuable genre of gesturing. Indeed not. Nor is it to suggest that gesturing for depiction does not include other means of gesturing. It almost always does. I simply isolate the genre as a way to investigate in great detail one use of gesturing in interaction for teaching and learning.

Defining practices for depiction. As I am interested in uncovering how gestural activity for depiction functions to support communication, promote thinking, and regulate interactions, it is not enough for this inquiry to simply state that the gesturing action depicts. I go further to identify *how* it depicts. What practices are used to bring a depiction into being and how do these practices shape the function of the gestural activity in interaction? Adding such specifications to the general act of depiction is necessary because how depictions come into being point to the possible functions the depiction may be serving for all the participants. Streeck, Kendon, and Murphy, demonstrating the move to define gestural activity by the work it does, offer categories for definitions for depiction practices that can be used in the process of analysis (Kendon, 2004; Murphy, 2003; Streeck, 2009). I borrow here from these categories and add to them. The terms I use to define gestural activity stem directly out of the data and were created to explain how gesturing is used for depicting in these particular interactions. I focus on depictions that are created through the practices of modeling, enacting, referencing, and tracing.

Modeling. Depiction through modeling happens when the hands and body act as the object. The object is invoked as the hands and/or body becomes the material to craft

its form. Examples of this are when a fistful hand becomes an atom; an extended index finger becomes a strand of DNA. The arms and legs of an out-stretched body show the four bonds to atoms on a four-carbon chain molecule.

Enacting. Depicting through enacting brings an object, or idea into existence by highlighting an action. An example of this is when two hands, with palms open and facing parallel to the ground, move from a distanced position from one another to a position where one hand is layered over the other to depiction the action of shifting tectonic plates. Although the hands model plates, it is the enactment of the hands in motion that does the work to depict the concept of subduction.

Referencing. Depicting through referencing adds a feature to objects that are already in existence through modeling. It is often deictic. An example happens, for instance, when the right hand depicts an atom. The index finger of the left hand points toward the internal center of the fist-as-atom to highlight its nucleus. The left hand is referencing while the right hand is modeling. But finger points alone do not do the work of referencing. The wiggling of the right index finger when two hands are modeling DNA can work to reference one particular strand.

Tracing. Although only used rarely in this data, another depiction practice discussed is tracing. Tracing is where the hand acts as a pointer and traces out a feature of the object of action. The right is modeling an atom. And now the index finger of the left hand draws a circle around the hand-as-atom to show the elliptical pathway of electrons.

Depiction Practice	Definition	Example
Depicting through Modeling	Hands evoke some relationship to an object	Hands as a fist to call forth an idea of an atom
Depicting through enacting	An object or idea is brought into existence by performing an action.	Two hands palm open, facing parallel to ground move from a distanced position from one another to a position where one hand is layered over the other as speaker explains movement of tectonic plates as subduction.
Depicting through Referencing	Adds a feature to object that in already in existence. Often referential and deictic.	Right hand is atom. Left finger points nucleus of atom. Left hand is referencing
Depicting through tracing	Adds feature by tracing or drawing out	Right hand is atom. Left pointer fingers draws circle around hands as atom to show pathway of electrons.

Figure 4.1. Depiction practices

I describe depiction practices and functions from the multiple viewpoints of the many participants. Changing viewpoints from participant to participant is important because often maker's gesture can be intended to serve one function but may be serving a different function for the recipient.

Elements of depicting practices. Elements of the depicting practices include the relationship of the gesturing with talk, gaze, and posturing, the space in which the gesturing is performed, the size and shape of the gestures and the timing and order of their presentation. All such elements of depiction practices give clues to how the gesturing is functioning in and for the interaction.

Talk. Gestures often happen in combination with talk. They often partner with speech to complete a full articulation of a statement in interaction. (e.g.: Kendon, Goldin-Meadow, McNeill). Particular referents to gestures in speech may coincide,

precede or follow the gestural depictions. I note where gestures fall in relationship to speech to help determine how they function in the interaction.

Gaze. A maker's gaze also provides information on how gesturing may be functioning (Goodwin, 1986, 1992, 2000; Stevens & Hall 1998; Streeck, 2009). Gaze can serve to coordinate turn taking (Goodwin, 2000; Stevens and Hall, 1998; Streeck, 2009), gain attention of an interlocutor (Goodwin, 2000), and indicate an object to which attention should be focused (Goodwin, 2000). The gaze of the non-speaker also provides information to the speaker of his recipient's attentional orientation (Goodwin, 2000). Gaze can be direct and aimed to the maker's own hands or focused on the recipient. Gaze can also be indirect and unfocused, neither on the hands or the other participants but off into the global space.

Space. The spatial orientation of the gesturing activity also provides information of how the gesturing may be functioning (McNeil, 1982; Ozyurek, 2000; Streeck, 2009; Sweetser & Sizemore, 2006; Williams, 2008). The entire interactional stage can be divided into three main gestural spaces – the self-space (Laban, 1928), the interactional space and the “collaborative space” (Williams, 2010). The space near the maker's body, often out of a direct sight line of other participants, is the self-space. This gesture space is often used for thinking out ideas. In the process of communicating an idea to another the maker may use the self-space to consider facets of the depiction before pressing it into the interactional space. The recipient may also reproduce a gesture in the self-space as a thinking tool used to consider facets introduced by others.

The space that extends outward beyond this self-space and does not cross the center-center point on the interactional stage is the interactional space. Gestures often

move to the interactional space to communicate ideas, whether declarative or interrogative in nature. Gestures performed in the interactional space can also be used to claim or hold the floor.

Finally, there is the collaborative gesture space. This breaks down the proprietorship of the interactional space. It is often the center-center of the interactional stage and used by all participants. The collaborative space can be used to jointly build a gestured depiction. It can also be used to pass along a gestured depiction to another.

Examining all such uses of space for gestural activity helps to identify the functional role of the gesture for the participants.

Size and shape. The shape and size of the gesturing and the motional expenditure with which it is performed also provides evidence as to how the gesturing is functioning. I attend to the relative completeness of the gestural action performed. Gestures can be complete and full as well as abbreviated and partial. Gesturing that is complete has a definite beginning and end point. McNeill (2009) has referred to these sorts of gestures as “crisp.” They make a fully contained statement. Gestures that are performed as abbreviated and partial are defined here as being “marked.” I borrow this term from dance. It is not to be confused with the idea of marking in linguistics and discourse analysis. Marked in dance is an abbreviated version of the full dance movement. Marked is enacted in half-performed actions. “Marked” in dance often holds only part of the choreographic phrase and not all of it. It acts as a short hand, note-taking practice to review, work through or ground knowledge of a movement phrase. When I refer to features of gesturing as “marked”, I mean to show that the action is abbreviated, not completed in full, and often only part of the whole.

Timing and order. When gesture occurs, how long they are present, and in what sequence they appear also contributes to understanding how they function and are intended to function. I consider timing and order not only with talk but also in relationship with the other above-mentioned elements.

All these element of practices for bringing depictions into existence work together to compose a functional use of the gesturing in interaction. As an analyst paying attention to such practices and elements helps make sense of the participants gesture use.

Defining functions of depictions. I define three broad functions of gestured depictions. First, there is gesturing that works to communicate. I refer to these gestures as “for you”. That is, the maker intends them for the recipient. Next, there is gesturing that is invoked for thinking. I refer to these gestures as “for me”. That is, the maker uses them to work through ideas. Lastly, there is gesturing that is used to shape and drive the interaction of participants. I refer to these as gestures, “for us”. The entire gestural activity is not just one of these, not just “for you”, “for me”, or ‘for us”, but a combination of all that work together to complete the final achievement and goals of participants. Functions can exist simultaneously and overlap one another.

Functions also are defined from the viewpoint of all participants. The speaker may use it as a source primarily for communication. The recipient, however, may also pick the same gesture-as- communicative as a means to identify the next interactional move; using it also as a gesture to direct interaction. In this project, I consider how the functions of the same gesturing activity can differ as participants work to achieve explanation and understanding in interactive explanations.

I again must stress that it is impossible to assign a sole function to gesturing in interaction. What I aim to do is to parse out, for the purposes of this inquiry, functional capacities for gesturing and identify what roles are in operation as I consider when gesturing is performed, how it is performed, and for whom it is performed. Following, I elaborate on the functions of gestural depiction for communication (gesturing “for you”), and gestural depiction for thinking (gesturing “for me”), and gestural depiction as it serves to regulate the interaction (gesturing “for us”).

Depicting for communicating. Gesturing “for you”. At times gestural depicting is intentionally intended by the maker to be used to communicate something to a recipient. They are intentionally public displays. Depicting for communicating includes such features of depiction practices by the maker of (1) performing the gestural activity in the shared interactional space, (2) performing the gesture in the projected sight line of the recipient, (3) calling attention to gestural activity through various means such as a maker’s gaze directed toward his hands, an emphasis to gesture by performing beats, an attention to gestured depictions through the use of terms such as “this” and “that”. Gesturing as an activity of depicting for communicating is often performed fully. Gestured utterances are sequentially linked and ordered in order to communicate a complete idea.

Depicting for thinking: Gesturing “for me”. Gesturing can support thinking by being an activity that happens strictly for the maker or an activity that happens between interlocutors, making gestures both as support for individual thought and a resource for thinking in the world. Depicting for thinking includes such practices by the maker as (1) performing the gesture closer to his own body and on the periphery of the shared

interactional space, (2) performing an abbreviated version or aspect of the entire gesture (referred to as “marked”), (3) gaze may not be directed to hands (this will be addressed further in the following discussion), (4) talk may present a mismatch with gesture production, (5) talk begins to resemble self-talk as the voice drops and words trail off.

Depicting for regulating interaction: Gesturing “for us”. Gesturing in interaction is also a social project. Depictions, although primarily intended to bring an object, action, or idea into existence through the use of the body, are also part of the social interaction. How a gestured depiction is employed gives it opportunity to be used as a conductor for the interaction. For example, when a maker engages a depiction for thinking in the presence of another the gesturing is also always potentially communicative by the mere fact that it is made public and thus visible to other interlocutors. And by virtue of being public, gesturing for thinking, as well as for communicating, also has the potential to shape the interaction. For example, when a speaker is thinking out directions that were just communicated to her, she performs a gesturing action in her self-space that indicates a right turn. The demonstration of the incorrect direction moves the other participant to step in and make the correction. Here the gesturing not only communicates and supports thinking, but also identifies and shapes participants’ next turns.

Ways of experiencing the depiction for thinking. Following I concentrate on gestured depictions for thinking. I explore the nuances in the differences of how gestured depictions are perceptually experienced. Because gestured depictions are made with our own body, they are inevitably experienced in our body. But the hands can also create actions and shapes that resemble models that, although, made with our hands, are treated

as objects outside of our body. That is to say that the gestured depiction we create can be seen as objects of our observations as well as visceral experiences in our bodies.

For example, when experiencing the concept of a 180-degree rotation of a molecule, the thinker can enact the rotation as an action, rotating the hand at the wrist toward the body, beginning with the thumb facing upward and concluding with it facing downward. The maker can observe that action, gaze focused on the hands. The hands act as an external model where information they provide is apprehended through the act of seeing. I refer to these gestures as capable of being “visually” experienced. But because the body is enacting the external model, there is simultaneously a felt experience. The action can become a sensation that is experienced in the body. For example the rotation of the molecule is made clear not simply by the visual representation of the 180 degree flip of the hand but the actual felt experience of the wrist rotating in space. I refer to these enactments that are felt in the body as being “viscerally” experienced. Both ways of experiencing, by the very nature that the gestured depictions are made in our own bodies, can be present simultaneously. I would, however, like to suggest that a maker can also choose to privilege one perceptual experience over the other.

Depicting for thinking: Privileging the visual experience. The maker can choose to treat the depiction made in her hands as a gestured object to be observed. The hands are primarily used as graphical references where information is drawn out through the act of seeing. An action that suggests a maker is giving emphases to the gestured object, as something to be apprehended visually, is when the maker’s focus goes to the hands.

When depicting for thinking is used to support a visual experience, the gesturing action

can be pulled in closer to the speakers' body but the gaze remains still on the hands. Posturing often softens to frame the gestured object.

Depicting for thinking: Privileging the visceral experience. Gesturing can simply be performed and does not need to be directly observed by the maker. The perceptual experience privileged is haptic and kinesthetic. Information is apprehended through a felt, physicalized experience. When a maker chooses to privilege the visceral experience of gestured depictions, gaze does not go to the hands. The visceral experience of the hands in action points to the idea that some knowledge emanates from a bodily felt experience of knowing (Becvar et al; Ochs et al; Streeck, 2009). The hands and body, instead of being used as a resource set outside of the body, become containers for holding information that can be experienced in the body.

I propose that one of these ways of experiencing the gesturing, either as visual or visceral, can be privileged over the other. For example, my son counts out three fingers on one hand and five on the other and looks at the representation to conclude that this equals eight. The information is seen in his hands. Two fists banging into one another to produce the information that sometimes molecules collide, may never be observed, but rather felt in the action of the hands coming together.

Experiencing gestures both visually and viscerally can also happen at the same time, one experience reinforcing the other. Watching my hands punch out the telephone number on an imaginary key board can render the spatial orientation of the telephone numbers as well as give me the felt experience of the fingers moving across the keyboard in a specific pathway, recording the information by looking at my hands AND feeling their movement in space.

I propose these distinctions to support analysis because understanding the differences of perceptual modes of experiencing gestures can help uncover some of the complexities involved in thinking. Under this distinction, a gesturing body offers different perceptual pathways to knowledge and meaning making. On one end of a continuum knowledge lives in the image the hands create, and on the other end knowledge lives in the kinesthetic experience the body undergoes.

Embodied vs. Incorporated. This brings me to a discussion about knowledge that is defined in multiple ways as embodied. This term is used often when discussing gestures. It has come to carry sporadic meanings that are not always accurate for this discussion. Embodied generally, but not always, refers to any action done with the body regardless of how it is experienced. (The term is used in this way through out the dissertation). In order to make the distinction between knowledge that is absorbed in the body and knowledge that is expressed imagistically with the hands as material, I use the term “incorporated”. Incorporated describes knowledge and experiences that are absorbed in the body. For example, drawing on my expertise as a dancer, it is evident that a good performance is not only the execution of the moves. The artistry is found when the dancer *becomes* the movement and the movement overtakes the dance. Incorporated is when the cognitive work of remembering steps, the placement of the arm, the timing of the turn, is no longer needed because the knowledge of the choreography is “incorporated” in the dancer. Another example of this is riding a bike. Once we have mastered how to balance we no longer need to think of the mechanisms that allows us to do so. That knowledge is now in the body. That is to say, that the knowledge is “incorporated”.

As an analyst who observes human behavior, how can we tell the difference between embodied actions and incorporated knowledge? Borrowing from my experiences as a dancer, I look to micro changes in the entire body to help identify what knowledge has reached a level of being incorporated as opposed to being only enacted. I look at nuances of the entire body with the same rigor we do with language. I observe, to the best ability the recording devices allow me, the physiological changes in the body. Movement that reverberates through out the entire body may more likely suggest knowledge that is incorporated. Analyzing the movement of the body to recognize the softening of the sternum, the slight downward motion of the ribs. Little to no movement emanating from the postural core can suggest otherwise. Such observations allows for the emerging investigation into differences of actions that can point to a level of bodily knowing where knowledge becomes part of the person in the body as well as in the mind.

Conclusion: Embarking on the Analysis

As this project aims to examine the functional role of gestures, accepting that these roles are multiple and dynamic, it becomes important to look beyond just the morphology of the gesture to understand how it is participating in teaching and learning interaction.

Understanding gesturing as an action is also necessary. Equally, it is essential to also look beyond the gesturer. The terms and definitions I have laid out help explain the function of gesturing for depiction as an interactional activity shaped by both the communicator and recipient. Terms first aim to show that functions gesturing perform are a result of the practices and elements the gesturing assumes in the specific situation in which is it being used. The terms and definitions spelled out in this chapter aim to better serve the

perspective that gesturing in interaction supports thinking as it happens in the head, in the body, and in the world, that gesturing is both a communicative act as well as a cognitive one, and that gesturing, as it happens in the presence of others, is also a kind of “social orchestrator” that shapes, motors and directs interaction.

CHAPTER 5

STUDY 1: EXPLORING GESTURAL PRACTICES FOR THE BUILDING OF COMPLEX CONCEPTS IN FACE-TO-FACE INTERACTIVE EXPLANATIONS

Introduction: Gesturing “For You”, “For Me”, “For Us”

In this first study I demonstrate that a speaker’s gestures and posturing are tactically employed as (1) communicative resources; (2) cognitive resources and (3) interactional resources. That is, (1) gesturing strategically slides between serving as communicative acts meant for the recipient. Taking the maker’s perspective, I refer to these as “for you” gestures. They act as thinking resources for the speaker. Taking the maker’s perspective, I refer to these as “for me” gestures; (3) Gestures perform as social directors used to guide a learning interaction toward a joint achievement. Considering the mutually established goal of the interaction to achieve explanation and understanding, I refer to these as “for us” gestures. In this chapter I analyze segments from three interactions in which experts explain concept to non-experts and examine the functional use of participants gesturing using the frame of gestures for you, gestures for me, and gestures for us to further understand how gestures are discreetly used for teaching and learning in interaction. The analysis is made up of four examples from videotaped segments of two professors and one graduate student explaining concepts in microbiology, mathematics and animal biology naturally occurring, face to-face, one-on-one conversations to non-experts. Findings suggest that gesturing flexibly serves multiple functions, shifting across and between being for you, for me, and for us. The study further suggests that the

result of this functional range of gestures in interaction facilitates the joint achievement of new conceptual understanding for novice learners in face-to-face interaction.

As I have identified functional categories for gesture use as “for you”, “for me”, and “for us”, I further stress that these categories are very rarely independent of one another. The study supports that gesture function not just as an act of communication or only as a manifestation of a speaker’s cognition, but rather as flexible, overlapping media where functional roles are adapted moment-by-moment based on the contingencies and aims of the interaction.

Data and Analysis

The following excerpts are pulled from the larger data corpus that consists of video-recorded conversations in which experts in STEM (Science, Technology, Engineering, and Mathematics) fields explained complex concepts to non-experts. Expert participants came from a pool of volunteers who responded to requests for participation. The non-experts in Study 1 are myself and another researcher who have little training in the STEM disciplines. Conversations were held primarily in the offices and labs of the experts and lasted between 30 and 60 minutes. Experts discussed topics of their choosing which they deemed as relevant concepts to their defined discipline and/or research. Expert participants were not aware of my interest in gestures and were not instructed to use gestures in their explanation. Thus, all gestures produced by the experts are naturally occurring. One of the limitations (resolved in the second iteration of data collection) is the presence of the researcher as conversational partner. To overcome some of these constraints, the researchers operated on the condition that we would not introduce new

gestures but respond to expert gesturing if it was a necessary part of the interaction. We also aimed to authentically understand the concept well enough to re-explain it to another.

As I was interested in the interactions between experts and non-experts, the following segments were chosen for analysis for Study 1 because they exemplify moments in the data in which the interactions take a conversational format for exchange of knowledge, as opposed to a lecture-like format in which the expert delivers information and the learner is relatively passive. Concentrating on data where conversational exchanges were present allows me to include the interactional arrangement as a unit of analysis.

The analysis takes a micro-ethnographic approach of videotaped interactions in which I analysis talk and action turn-by-turn (turns both in talk and gestures). Such process allows for a close investigation of how the hands and body are pressed into service in interaction explanations for the teaching and learning of STEM concepts.

The Findings: Discovering Categories of Phenomena

The following analysis reveals three key categories of phenomena. In the service of jointly building conceptual understanding, the outlined examples show that gestured depictions are (1) built step-by-step for and with the recipient, as they are positioned and adjusted for the recipient, (2) used to correct the learner's misunderstanding (in response to the learner's gesture), (3) used by both the explainer and the recipient to drive the interaction toward the shared goal of achieving understanding. Together the examples demonstrate that gestured depictions slide across multiple functional roles to support

communicative activity, cognitive/thinking activity, and interactional activity, and this contributes to the achievement of joint understanding in face-to-face interactions. Such findings contribute to a deeper more refined understanding of the role of the body in interaction for teaching and learning and give opportunity to inform teaching and learning designs that make use of the expansive functional role of gestures and the body.

Example 1: Expert builds the depiction step-by- step for the recipient. In the example to follow I show how in the process of explaining the structure of DNA, an expert employs the hands and body to build up a concept step-by-step for her recipient.

The setting: Student lounge in a chemistry department

The concept: The architecture of DNA

The participants: *Sakina*, a graduate student in molecular biology

Sari, researcher conducting the interview

Hands-as-DNA - A gestural depiction that consists of index finger of both hands displayed in the vertical dimension

Below I offer a transcript of the talk (see Figure 5.1). Actions will be further highlighted in visual frames accompanied by the talk in the analysis to follow.

“Two strands”

- | |
|--|
| 1. SAKINA: So when you have DNA |
| 2. inside of the nucleus of a cell |
| 3. Then there are two strands. |
| 4. And the stands have a direction |
| 5. So one strand we call is five prime end and a three prime end |
| 6. And its bound to a strand that is kind of (.) anti-parallel to it |
| 7. So there’s a three prime end (.) across from the five prime end |
| 8. And now this is your other three prime end near your five prime end |
| 9. SARI: Okay so you have the(.) two stands = |
| 10. SAKINA: So you have two [stands] |
| 11. SARI: [two stands] |
| 12. SAKINA: so like this. |

Figure 5.1: Transcript of talk from Example 1

Step 1 – Presenting the Gestured Depiction “For You”. As Sakina begins to explain the replication of DNA, she first sets up the basic architecture of DNA. She introduces the structure of DNA into the interaction through talk and actions. Her hands and body move with her talk as she says, “So when you have DNA inside the nucleus of a cell then there are two strands” (see Figure 5.2). Together, the talk and action construct the concept of DNA as having two strands for her recipient.




		
1. SAKINA: So when you have DNA	inside the nucleus of a cell	2. then there are two strands.
<i>Sakina gazes to hands</i>	<i>Sakina gazes to recipient</i>	<i>Sakina creates depiction and gazes to recipient</i>

Figure 5.2 Sakina presents the gestured depiction

Sakina achieves this construction in a coordinated orchestration of talk, gaze, and gestures. First Sakina’s gaze drops to her moving hands that have just lifted off her lap as she states “So when you have DNA ...”. The word “so” is partnered with the lifting hands as a preparation move towards the performance of a bodily demonstration for her recipient. As she continues with “inside the cell of the nucleus” her gaze moves to her recipient as her hands seem to create a circular shape as she utters “cell”. As she proceeds with “then there are two strands” her gaze shifts back to her own hands. Here she simultaneously lifts her two index fingers, positioned side-by-side. As she says “two strands” she glides her fingers downwards--drawing two spiral lines in space (see Figure 5.2). Sakina’s gaze returns to Sari as the movement and talk conclude. She holds the

shape of the hands with two extended index fingers in a brief moment of silence. The first appearance of the depiction of DNA as two strands is complete.

The interplay of practices and elements contribute to the construction of the depiction.. Her practices for depiction include modeling the DNA as she lifts her two fingers. It further includes the practice of tracing as she moves her fingers downward in a slight spiral motion to indicate that the strands extend beyond the length of her finger and that structure of the strands maintain a slight spiral form. The gestured depiction is complete and crisply present.

Sakina's making of the depiction is a communicative act meant for her recipient. Through her building, Sakina has also established for her recipient that the gesturing she is performing is an important to her explanation and that her recipient is expected to attend her gesturing , One way she does this is by claiming the recipient's attention to her gesture through shifts in gaze. When Sakina first begins to set up the primary gesture in unit 1 she gazes to her own hands as she says, "When you have DNA...". As she continues with "inside the nucleus of your cell" her gaze goes to the recipient. As she says "then" at the start of unit 2 she extends her index fingers and shifts her gaze down to them. As she moves her fingers into position to begin the two downward motions that will mark "two strands" she gazes back at Sari. This alteration of gaze to gesturing hands, to her recipient and back to her gesturing hands is an example of a routine way of establishing joint attention to an artifact. In this case, the artifact is a depiction made by her hands.

In this short stream of talk and action, Sakina has achieved the building of a depiction that gains the attention of her recipient. The coordination of her talk and action

(across only 16 words) has defined the interactive nature of the teaching and learning arrangement as one in which (1) Sakina is going to use talk and action to communicate information and, (2) the recipient has the interactional responsibility to take notice of her explainer's hands if they are together going to be successful at the task of explaining and understanding the concept. The gestured depiction is thus communicatively (gesturing "for you") and interactionally (gesturing "for us") serving the goal for teaching and learning about the structure of DNA.

Step 2: Adding Elaborations To Gestured Depiction "For You". In the next step Sakina adds elaborations to the recently constructed depiction.




		
4. SAKINA: So one strand we'll call it five prime end and the three prime end.	5. And its bound to a strand that is kind of	anti-parallel.
<i>Sakina's hand drops out to make elaborations</i>	<i>Sakina's hand returns to create depiction in entirety</i>	<i>Sakina's gaze goes to recipient when statement is complete in talk and action.</i>

Figure 5.3. Sakina adds elaborations to gestured depiction

Sakina, having already established the structure of DNA as two strands moves to show that the strands five prime and three prime ends (unit 4) are "anti parallel" (unit 5) to one another. In this process of elaboration, Sakina adapts to the constraints of having built a model using both hands as modeling resources to needing to invoke one hand as a referencing resource to highlight details. When she pulls out the right hand to serve as a referencing tool, the full depiction dissolves to only half of its complete construction. The

one hand is able to stand and in represent the model of the entire two-stranded DNA, while the other does the work of guiding the recipient to the specific parts of the stands. As Sakina speaks, “so one strand we call it the five prime end and the three prime end”, her right index finger points to a spot toward the tip of her left extended finger (see Figure 5.3) and then another spot towards the base of her finger. The gestural practices in the process of creating the depiction moves from presenting the whole and then highlighting specifics as the hands move from modeling the thing – the DNA – to deictically referencing aspects of the – “five prime and three prime”.

Once specifications are pointed out, Sakina immediately replaces the hand as reference tool to resume its role as a modeling resource to re-create the complete model of two strands. This time when Sakina adds the right hand back in to the depiction to model the two strands of DNA she also alters the construction to show that the strands go in opposite directions, adding more information to the concept in her continue process of building. She does this by straightening her right index finger and then flipping the hand so that the finger is now parallel to the left index finger, but pointing downward (see Figure 5.3). As the second version of the depiction is complete, she torques her body and shifts the depiction toward Sari into her sight line. As she utters “anti-parallel” (see Figure x) her focus moves from her hands and back to the recipient., again a demonstration works to achieve a mutual orientation to her hands as objects to be attended to. Beyond gaze as a directing element to guide the recipient to the gestured depiction, there is also a rhythmic coordination of talk with the gesture when she utters “anti-parallel” and accents the gesture with a slight beat.

Sakina highlights her gestural depiction in order to depict a concept and indicate to the recipient it is worthy of attention and part of the explanation by the manner in which she produces it. It is positioned for visibility. The movement is deliberate, direct and steady, and punctuated as to call attention to her depicting hands. Gaze goes to recipients upon completion. In the pause in talk, her hands are poised for her recipient. Her hands and arms are lifted, framing the depiction and creating an impression of purposefulness (see Figure 5.4).



Sakina torques body and adjusts depiction in sight line of recipient

Figure 5.4. Sakina continues to add elaborations to gestured depiction

The work to build the depiction step by step for her recipient is confirmed as Sari tilts her head to see Sakina's hands. Sakina respond to this move by repositioning the depiction more clearly in Sari's sightline as she shifts her hands to her right (see Figure 5.5). This move by the recipient displays Sari's recognition that the built gestured depiction is for her, and that this information is consequential for her understanding.



Figure 5.5. Participants perform mutual adjustments to depiction

Interactionally this last shared adjustment where Sari tilts her head to see the depiction and Sakina repositions her body for her to more easily do so, demonstrates the depiction as taken up as shared object.

Example 1 has revealed that in the process of explaining a complex concept to a non-expert, an expert employs the hands and body to build up a concept step-by-step for her recipient by first presenting the concept and then adding elaborations. The process of building the concept involves making the gestured depiction available to the recipient, establishing the gestured depiction as a share object of talk important to the explanation. The gestured depiction in the hands of the explaining is a communicative resource for the recipient. Here it is a gesture “for you”.

Example 2: The recipient takes up the gestured depiction. In the following example I show how the recipient takes up the gestured depiction and uses it as resource to clarify her own understanding. In this sense, it becomes an artifact for her benefit – a gesture “for me”. But Sari also uses the gesture to clarify her understanding by publically

displaying it for Sakina, also allowing her reconstruction of the depiction to simultaneously be a gesture “for you”. The movement between being “for me” and being “for you” establishes the gestured depiction as a shared resource in the interaction that works “for us” to move toward the achievement of mutual understanding of the structure of DNA.

After Sakina reaches a completion point in her explanation, her hands come to rest. Sari, recognizing the turn has come to a close as hands drop to her lap, takes the floor. She initiates her turn by taking up the depiction, copying the previously constructed gestured-depiction invoking DNA strands. When Sari displays the gestured depiction she states, “Okay, so you have two strands” (see Figure 5.6).



Figure 5.6. Sari takes up gestured depiction

The immediate take up of the gestured depiction shows that the gestured depictions has been successfully built, and recognized by the learner as important to the explanation.

Sari's take up not only functions to show her alignment with the explainer, it further is used to advance understanding. As Sari lifts her hands she says, "Okay, so you have two strands." But her confirmation is incorrect. Sari shows the parallelism of the strands but fails to show the opposing directionality that Sakina demonstrated (see Figure 5.7) in the building of DNA as anti-parallel.

Sari's uptake becomes a demonstration of her misunderstanding in need of clarification. Sakina is keenly aware of Sari's gesturing hands as they fail to demonstrate the salient point of directionality. In Sakina's next turn, Sakina uses Sari's demonstration to repair her misconception.

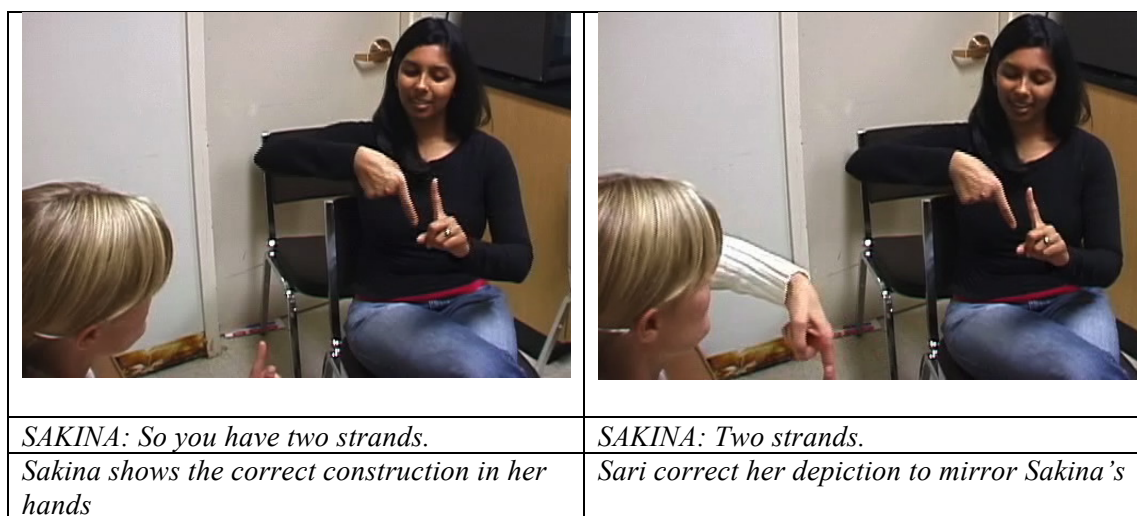


Figure 5.7. Participants repair misunderstandings through gesture

She repeats the learner's previous phrase, "So you have the two strands", as she demonstrates the anti-parallelism in her gestured depiction. Sakina shows the correct construction in her hands. The talk is the same; it is the gesturing that provides the correction. Sari, attentive to the gesturing as a critical demonstration of information, sees this and flips her hand to mirror Sakina's and repeats "two strands" (see Figure 5.6) thus repairing the misrepresentation to reflect the correct directionality.

This example shows that gestural depictions do get taken up, and are picked up immediately. The uptake distinguishes the gestured depiction as built. It shows it is recognized as consequential to the explanation and thus pronouncing it as a solid artifact of talk. Now part of the interaction, the gestured depiction is invoked by both participants to participate in the mutual goal – that is the explanation and understanding of a concept. And as the accepted gestured depiction is summoned to support the goal, it is mobilized in varied ways to move to that achievement. So the taking up of the gestured depiction does more than just invoke an artifact, it becomes a vehicle for action that will shape the interaction to come. In the hands of the explainer it has already done the work of communicating information to a recipient (gestures “for you”). In the hands of the learner it has worked to organize her own thinking (gestures “for me”). And the hands of the learner it has also communicated how the learner is thinking about the new information, essentially making her thinking visible and creating an opportunity for clarification that will help achieve the goal. But the immediate uptake established another function that will support the trajectory for teaching and learning. It becomes a source used to direct a kind of turn taking that unfolds into understanding (gestures “for us”). Sari and Sakina pass the gestured depiction back and forth to collaboratively build the correct statement. In short, when a recipient takes up a gestured depiction in an interactive explanation the gesturing expands its functional role, acting as a communicative tool “for you”, a thinking tool “for me”, and interactional to “for us”.

Example 3: Explainer assumes the perspective of the recipient. Another indicator that gestures can be intentional teaching tools meant for the recipient is when an explainer shifts position to assume the recipient’s perspective on a gestured depiction. In

the field of Discourse Analysis this perspective taking is referred to as recipient design. Recipient design is the capacity for crafting communicative behaviors for the recipients (Sacks, Schegloff & Jefferson, 1974; Stevens, 2012). Recipient design is often studied as it is reflected in talk. I turn to another example that shows recipient design processes are also reflected in the presentation of a gestured depiction. I refer to this as “embodied recipient design”. The embodiment of a recipient’s perspective on a gestured depiction supports the idea gestures are often designed “for you” that maker’s go to the extent to understand how their recipient “see” the gestured depiction.

The setting: Professor’s office

The concept: Dimensional geometry

The participants: *Max*, a highly ranked professor of mathematics

Sari, researcher conducting the interview

Hands-as-dimensional model

Max, a professor of geometry, explains the concept of four-dimensionality. First, he explains a more basic concept: three-dimensionality. Max creates the depiction using the fingers to represent three dimensions (see Figure 5.8).

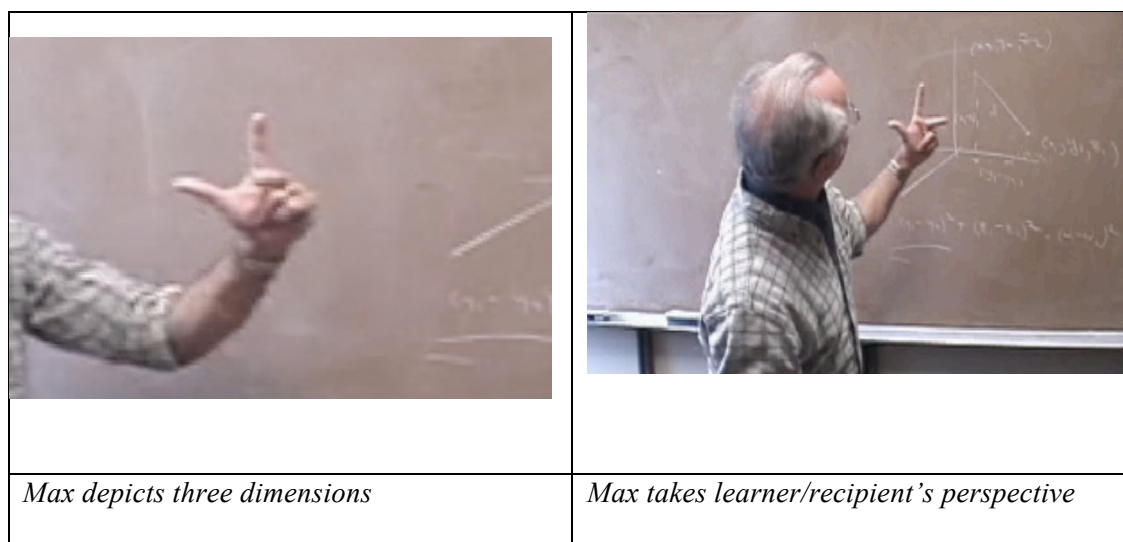


Figure 5.8. Explainer assumes the hearer's perspective

Once he settles on this construction, he then pauses in the process of explanation. He holds the gesture in its established space and, as though detaching himself from his role of maker of the gestured-object, he steps out of conversational space, crosses the interaction field and observes the built depiction from the recipient's visual perspective (see Figure 5.7). Max steps into the physical position of the recipient in order to "check out" how the gesture looks from that perspective

Here is a clear representation of what I will call "embodied recipient design". Max uses his body to take the visual perspective of his recipient in the process of composing a gestured depictions to serve his explanation. This clearly shows that the explainer's gestures can be unequivocally of the "for you" category so much so that he momentarily becomes the "you".

Together these three examples suggest that teaching includes the use of the hands and the body as resources to communicate information and direct interaction. It also suggests that formative assessment of a learner's understanding happens not only in words, but also in the back and forth exchange of gestural representations between expert

and non-expert. The examples show that gestured depictions used in interactive explanation are both functionally flexible and dynamically facile.

Example 4: Gestures move between participants to evolve understanding together. In the example to follow I explore more deeply the dialogic nature of a gestured depiction in interactive explanation and show how gestured depictions move between participants to evolve understanding together.

The setting: A Biology professor's office

The concept: Oxygenation in fish

The participants: *Mara* – Mara is a Professor of Biology. (Mara appears on the reader's right side of the frame)

Steph – Steph is the researcher as interviewer (Steph appears on the reader's left side of the frame)

Hands-as-gills - gestural depiction that consists of an open hand with spread fingers

In this sequence we see several of the phenomena discussed so far. For instance:

- Gestured depictions are constructed for the benefit of the learner.
- Gestured depictions are used to repair and clarify the learner's misconceptions.
- Gestured depictions participate in the moment-to-moment assessment of where the learner is in the process of understanding.

Although these phenomena are present in the next example, I give particular attention to how the gestural activity for depiction moves back and forth between expert and learner to work toward a shared understanding of a scientific concept. I show how the function of the gestured depiction continues to shift as it is passed back and forth between the expert

and learner. This interactional volleying back and forth of the gestured depiction and the changing function it takes as it moves from hands to hands promotes a process for transforming conceptual understanding together.

This segment is made up of 6 turns and demonstrates how the gestural depiction moves between functions and between participants in a trajectory to get to understanding. Mara, (a biologist) explains how fish gills function. Mara, in response to the learner's question about the shape of a fish's gills, moves the discussion away from the process of oxygenation and on to the relationship of surface area to oxygen consumption.

The specific gesture that is the focus of this discussion is made up of an open hand with the thumb pulled to the palm and four fingers loosely separated (see Figure 10). The gestured depiction is a modeling invoking gills of a fish. Mara introduces the gestured depiction by placing it in the center of the interactional space in the learner's sight line and asking, as she gazes to her own hands, "But what does this give you when you are like that?" The central placement of the gesture and the use of deictic pronouns "this" and "that" direct the learner's attention to Mara's gesturing hand and the specific shape in which she is holding it. These practices identify the gesturing for depiction as a communicative act meant for the recipient.

Through the depiction practice of modeling Mara presents the "hand-as-gill" gestured depiction. Her body remains on the very outside edge of the interactional space (see Figure 5.9) while the gestured depiction takes a central position in the interactional space. By remaining on the periphery and foregrounding the built gestured depiction, Mara's body positioning further initiates a passing over of the gestured depiction to the learner. The learner responds by mimicking the depiction (see Figure 5.8).



Figure 5.9. Participants pass the gestured depiction

This take up of the gestures depiction, as in other examples, demonstrates the gestured depiction of the “hand-as-gill” has now been established as a shared association central to the explanation. Now in the hands of the learner, Mara drops her gesturing hand out of the center of the interactional field. Steph begins to act upon the gestured depiction. The pass has thus been completed. Mara steps out of explanation mode as she drops her hands to her lap and allows the learner to slip into an exploration process (see Figure 5.10).



Figure 5.10. Learner thinks through with the gestured depiction with the expert

In the hands of the learner the gestured depiction becomes a manipulable tool used to work out an idea, i.e., a depicting for thinking. This shift of function as it moves from the expert's hands to the learner's is evident from the learner's treatment of the gestured depiction. She performs the gesturing in the periphery of the interactional space. She draws it closer to her own body and performs actions on the gestured depiction in an abbreviated manner. The gesture, now a depiction for thinking in the hands of the learner, is used by the learner to explore various relationships between a fish gill and water under the supported presence of the expert. As the learner's left hand models the "hand-as-gill" gesture, the right hand is used to simulate various aspects of the movement of water over the gill. The depiction practice of enacting allows her to explore pressure, impact, and flow (see Figure 5.11). For example, in one simulation the learner moves the fingers of her right hand (the right hand enacting the movement of water) between the fingers of the left hand (the left hand modeling the gill) and utters, "it [water] can get through."



Figure 5.11. Learner's depicting for thinking is made available to the expert

The learner's introspective focus, demonstrated not only by the abbreviated manner of her action on the gesturing hand, but also suggested by the slight pulling inward of her body to create her own frame around the gesturing, identifies the current function of the gesture as a depicting for thinking. But it is not just a thinking tool in use for the learner. It is part of a documentation that is meant to be seen by Mara – a depiction that also communicates thinking. The learner's choice to reveal her thinking to Mara through the visibility of the gestures and the audible "figuring out" talk suggests that the learner is seeking on-going guidance from the expert. The depiction for communicating thinking is also a request for support. The learner's vacillating gaze from an inward focus on her hands to outward gaze toward Mara also functions to keep the expert "on deck" as a resource while the learner works through learner's questioning. Mara picks up the Steph's bid for approbation and/or clarification and shows this as she shifts her body back into the space (see Figure 5.11) when the learner verbalizes an idea that may move her toward an understanding of the concept.

Other uses of the “hand-as-gill” as gestured depiction spin out of this interactional activity. In addition to acting as an evaluative tool and a thinking tool, the gesturing also becomes an interactional tool used specifically to organize and co-coordinate the teaching and learning to accomplish the task of learner understanding. Mara sits up from her reclined position and passes the depiction through the interactional space indicating to the learner that she is supposed to do something with it to uncover some answers. Mara and the learner use their hands and body as mechanisms to steer the direction of the conversation toward the achievement of the shared goal of understanding the concept in play. Mara uses the body positioning to direct the learning toward the kind of investigation that will get to conceptual understanding, and the learner, making use of the evaluative benefits of making her thinking visible, uses the hands and body to check in and assure that her exploration is on the right track.

Mara’s explanation occurs within a somewhat structured learning-teaching interaction. It is motivated by a pedagogical approach of guiding the learner through her own process of discovery. It is an example of an expert disciplining the perception (Stevens & Hall, 1998) of a non-expert through the use of the body. Mara could have very well responded to the request for clarification through a process of explanation, giving the learner the answer she seeks. Instead, she passes the gestured depiction to her, puts it in learner’s hands to work with in order to come up with the answer. The passing back and forth of the gestured depiction and its flexibility to assume multiple roles facilitated this self-discovery as guided by the expert. Again I show that the depiction itself slides across functions as a depiction for communicating a concept, a depiction for thinking through ideas, a depiction for communicating thinking (that in turn allowed it be

used as an assessment tool) and finally a depiction that shapes the interaction. These functions take form in the interaction and because of the interaction between expert and learner.

Discussion and Implications: Hands and the Body as Part of Interactive

Explanations

In this study I presented four examples that illustrates the ways in which experts and learners use gestures and the body to achieve explanation in interaction. I first showed that an expert builds gestured depictions step-by- step for the recipient. I then showed, that once built, that the recipient takes up the gestured depiction to clarify and publically display understanding for the expert. I also showed how an expert in the process of explaining goes to the extent to assume the perspective of the recipient in order to judge the depiction's effectiveness for communicating information. I finally showed that gestured depictions move between participants to evolve understanding together. The study reveals that in one-to-one, face-to-face interactive explanations that participants systematically and creatively used gestured depictions to serve communication (gestures "for you"), thinking (gestures "for me") and the interaction (gestures "for us"). The study further revealed that these functions do not exist in isolation with one another but rather partner with each other to serve the end goal of achieving joint understanding in teaching and learning arrangements.

Seeing gestures as serving cross-functional roles in interactive explanations for teaching and learning is an improvement on the dominant perspective of gestures primarily filling a cognitive role in teaching and learning interactions. Recognizing

gesture as serving multiple and changing roles that slide across functioning as communicative resources, thinking tools, and interactional resources allows for a broader spectrum for insight into uncovering the complexity of how gestures participate in teaching and learning. As hands are easily accessible and very present elements in interaction, knowing when and how we use them organically can help shape how we might use them intentionally.

Hands are a kind of depiction material always available. People often turn to gestural resources because of all the possible resources accessible gesturing may provide the best opportunity for the task at hand in a particular moment. They may, for instance, more efficiently depict a concept than words. They may offer another level of information that partners with talk. They may animate the talk, thus, offering two representations of an idea. Explainers may have these affordances of the hands in mind and engage in an active choice when moving to gestures. One example that suggests this is when Mara responds to the recipient's request to know why one physiological model for respiration did not survive evolution. In her on-the-spot planning for explanation, Mara considers various available resources. She finally settles on her hands as media to explain the phenomenon. Mara begins her explanation as she states "The reason they didn't work is because with..." Here she pauses, lifts an open hand, palm upward, into her near space. She gazes to her hand. She continues "with gills". At this point her hand drops out of the open palmed shape and hovers over the image on the paper she was using before to explain oxygen exchange. In a pause between talk, she immediately releases her hand hovering over the paper, glances to her computer screen and comes back to the open-palmed hand she first looked to as she adds the second hand mimicking

the other hand's shape. She pauses with her focus on her hands and continues. "Gills almost look like your hands". Mara seems to make a choice for the hands as a form for representations over others.

In all conversations, paper and pen were present in the interactional space. In all these examples, white boards, chalkboards, previously constructed images such as diagrams, and other tangible resources were within reach. All explainers, however, moved to gestural practices instead of other available resources. It is possible one reason the gestures were used was because they were the modality that best supplied the information. But effective representational tools are not enough for successful teaching and learning. It is also possible that explainers use gestures because they also maintained an active interaction with the learner. (In many cases to move to paper and pen, meant re-arranging the interaction and forsaking some face-to-face focusing that gets lost when an external media gets called in).

As gestured depictions are easy to make, they are not always as easy to be of use. First off, they are ephemeral and fleeting. They materialize when the hands are in action and disappear when the hands come to rest. They are also abstract. They do not offer a clean one-for-one representation of what they aim to signify. An upright, extended index finger is still a finger even though it is invoked to step in as representing a DNA strand. As gestures are easy to make and they happen often, they take effort to figure out how to use as well as how to make them useful in interactive explanations. For instance, as the data show, successful use means the maker needs to adjust them moment-by-moment to make available to a recipient. This requires the explainer to note whether the recipient is tracking the gesture. For the recipient it requires discerning which gestures are valuable

to the explanation and which ones are not. They also take mental work to keep them alive even when the hands come to rest. And they take an imaginative capacity to accept them as something they barely resemble.

But yet the analysis suggests that an explainer can successfully choose and use gesturing for depiction. It further shows that the recipient can take up the gestured depiction as use it as part of the process of the developing understanding. Gestured depiction, thus, can be used flexibly and across participants to perform multiple and simultaneous functions that are directed toward the achievement of mutual understanding. They can function as communicative tools to relay information and as potential thinking tools to be used by the learner to develop conceptual understanding. And they can also step in as interactional tools that give way to a kind of teaching and learning that allows for exchange and response between expert and learner, between sharing information and developing new understandings.

As Study 1 has revealed some provocative categories of phenomena of gesture use in interactive explanations between experts and not experts that include that gestured depictions are (1) built step-by-step for and with the recipient, (2) used to correct the learner's misunderstanding, (3) used by both the explainer and the recipient to drive the interaction toward the shared goal of achieving understanding, questions remain as to whether the phenomena hold up across other similar learning situations. In Study 2, to follow, these findings are further applied and further explored.

CHAPTER 6

STUDY 2: MADE BY HANDS - GESTURAL PRACTICES FOR THE BUILDING OF COMPLEX CONCEPTS WITHIN AN EXTENDED INTERACTIVE EXPLANATION

Introduction: Gestured Depictions Are More Than Brief Resources for Developing Understanding

Study 2 evolves out of the findings revealed in Study 1. I show that categories of phenomena uncovered in the prior analysis of brief segments, lasting less than a minute, of experts and non-experts using gestured depictions to build joint understanding of STEM concepts are also present in a single extended explanation lasting over 40 minutes.

Study 2 adds to Study 1 by revealing that the use of gestured depictions can persist and develop throughout an entire explanation, becoming a seminal resource for communicating and building meaning in interaction. This is an evocative finding because it shows the hands and body are not just single and brief resources used intermittently in explanations, as the prior short segments may lead one to conclude. Rather gestured depictions can also serve as coherent, critical, and central resources used strategically and systematically to build the teaching and learning of a layered and complex concept over time and across the development of understanding. Locating the same categories of phenomena distilled from the prior study and further scrutinizing how gestured depictions are used in interaction to establish and develop joint understanding across explanation of one single concept is important because it offers further insight into the function of gestures for explanation in which the entire concept is coordinated with a gestured

depiction and iteratively developed over the course of the conversation. Such findings encourage that new instructional designs pay even closer attention to how the hands and body can be pressed into service as intentional resources in instruction. (I add further to this claim in Chapter 8 with an analysis of multiple cases that further establish and extend the generality of these phenomena).

Data and Analysis

The data collected is a result of Phase Two of the collection process in which I replaced the researcher as recipient with volunteer participants who responded to recruitment emails. As I was interested in face-to-face interactive exchanges between experts and non-experts, I adapted data collection processes and chose to move the conversation from the offices and laboratories belonging to experts in order to break down the formal teacher–learner arrangement that seemed to shape conversations to mirror classroom lectures where information is passed on from expert to learner with limited interactional exchanges. As a result of this change, the recruited participants, Bram, Raya, and Ellie, were seated in an outside beer garden of a local pub on a late summer afternoon.

Initially, Bram was to meet with one non-expert at a time but due to last minute schedule conflicts, both Raya and Ellie were present for this explanation. As part of this study, Bram was instructed to discuss his work and to explain a concept related to his work. Bram chose the concept for discussion. Raya and Ellie were told that they were going to share what they gained from the discussion with another novice participant two days after this conversation. None of the participants were aware of my interest in gestures. They were simply told that I was studying explanation. None of the participants

were instructed or encouraged to gesture. All gestures occurred naturally within the conversation. This current analysis concentrates on the explanation event. (I will analyze the subsequent re-explanations event in Chapter 7).

As I was interested in how gestured depictions are built and used over time, I focused on the continued appearance of a single gestured depiction as it developed over the time of the extended explanation and across participants. This approach allowed me opportunity to closely examine the changing role of a single depiction across the explanation event.

The analysis takes a micro-ethnographic approach of videotaped interactions in which I analyze talk and action turn-by-turn (turns both in talk and gestures). Such process allows for a close and iterative investigation of how the hands and body are pressed into service in interactive explanations for the teaching and learning of STEM concepts.

The concept. The concept is based on the theory of bulk hetero-junction. (Although Bram does not use this term in the discussion analyzed here, he has explained the term in previous discussions with me (Scopelitis, Fieldnotes, 8/03/09). The theory of bulk hetero-junction proposes a molecular architecture for creating solar energy in which the electron donor and acceptor materials are blended and layered together. These active conductive, interpenetrating layers of materials are sandwiched between two electrodes to produce a transfer to induce an electrical current. The actual enacting of this theory requires sensitive control over material and morphology on the Nano scale. Bram explains that his lab is exploring molecular configurations based on the theory of bulk hetero-junction and that he is currently experimenting with thin-film semiconductors

constructed of organic material such as plastics (as opposed to the more costly metals often used). His research community anticipates that, once perfected, the materials can be deposited on different types of polymers to create affordable solar cells.

The participants.

Bram, the expert. Bram is a first year graduate student in chemistry with an undergraduate degree in engineering. He has participated in two other explanation events in which he discussed polymer solar energy as well. Bram works as a research assistant in a university lab where the team conducts research on polymer cells.

Raya, a non-expert. Raya holds an MFA in dance. She is a lecturer in the dance department and performs professionally in the community. Raya says that she has “not really thought of chemistry since high school.” (Scopelitis Fieldnotes, 08/03/2009).

Ellie, a non-expert. Ellie is graduate student in dance. She recalls enjoying chemistry in school. She goes on to say “If I weren’t a dancer, I might be a chemist.” (Scopelitis Fieldnotes, 08/03/2009). Ellie and Raya are colleagues in the dance department and are members of the same dance company.

The gestured depiction. “The “interwoven hands” depiction begins with the fingers of one hand interlaced within the fingers of the other. This depiction comes to represent the concept of a theory for polymer solar cell construction. I analyze the use of these gestured depictions and the auxiliary gestures that come to define it.

The Findings: Categories of Phenomena Extended

Study 2 gives further evidence to the findings in Study 1 as it also adds deeper insight into how the use of gestured depictions to describe and think through science concepts

can be integral tools for the achievement of joint understanding of complex STEM concepts, offering more insight for new designs for teaching and learning that make use of the body.

Phenomena extracted from the prior study that also appear in the following analysis are the following. (1) Experts build gestured depictions step-by-step for their recipients. (2) The use of the gestured depiction develops out of the perceived sense of a recipient's need to understand the concept. (3) Recipients take-up the expert's gestured depictions to extend understanding. (4) Both the explainer and the recipients use gestured depictions to correct the learner's misunderstanding. (5) Gestured depictions are used by all participants to think through concepts together as they are passed back and forth and treated as both cognitive and communicative resources in the pursuit of building understanding. (6) Gestured depictions are used by both the explainer and the recipient to steer the interaction toward the shared goal of achieving understanding. Adding to the prior analysis, the analysis also uncovers new phenomena that include (1) that learners use gestured depiction as both visual and visceral perceptual resources to support understanding, (2) gestured depictions accumulate meaning for the learner through out the explanation, and (3) gestured depictions used to explain a concept become a shared association used to extend questions and expand learning in the course of the explanation.

I divide the analysis into 4 sequential episodes that move across the entire 40-minute explanation. Each episode attends to a dominant theme. Collectively the themes exhibit that gestures depictions are more than present artifacts to boost explanation but are, in fact, seminal resources used to communicate and think through information in interaction. Study 2 further shows that an expert's successful use of gestured depictions

requires an attentive and systematic and creative coordination of all resources to achieve the effective affordances gestures and the body inherently hold. This adds to current research on the role of gestures by revealing that It is not enough for gestures to be present to support teaching and learning, they need to be strategically and creatively employed, and embedded in the context of the natural surround.

At the beginning of each episode, I provide a transcript of the talk and action. Each segment within the episode is further depicted using frame shots partnered with a transcript of related talk and a written description of the action. The talk that corresponds to the action depicted in the frame is boxed. I define a single phrase of talk or action as a “unit.” Each unit has a corresponding numerical identifier. A series of units makes up a segment. Segments make up the episode.

Episode 1: Building a durable gestured depiction. As depictions built by hand are often short-lived external models that dissolve when the hands come to rest, Episode 1 shows how Bram strategically constructs the gestured depiction to persist over time as an external model, even when the gestured image breaks down. His careful building lends to the depiction as being easily recoverable and thus more durable, able to establish prominence in the interaction with its very first appearance. The first appearance of the gestured depiction is first a depiction for communicating information about the concept to the recipients. However, Bram’s careful orchestration of practices for building a depiction to communicate also work to set up the to coordinate and organize the expected roles of all participants, including the depiction itself, in pursuit of the goal of joint understanding.

“ So if you have two like regions like that”

<p>BRAM:</p> <ol style="list-style-type: none"> 1. So if you have like two regions 2. that were like that (.) 3. And then have an electrode up here 4. and one down here 5. that would be somewhat ideal. 6. Because anywhere where (.) where you absorb light you 7. would be close to 8. the other material. Right? 9. You absorb light in this material. 10. You're close to the other material. 11. It hops over and then transfers down. (.)
--

Figure 6.1. Transcript of talk from Episode 1

Expert strategically constructs gestured depiction step-by-step for the recipients.

In the segment to follow I show how Bram, like Sakina in Study 1, builds the gestured depiction for his recipients step-by-step. His careful assemblage highlights the depiction not simply as something that is *part* of the explanation. Rather, his strategic construction renders the gestured depiction as *indispensable* to the explanation

Step 1: Introducing the “interwoven hands” depiction. As illustrated in Study 1, an explainer first brings the depiction into the conversation for his recipients. Bram begins this process by first setting the stage for the presentation of the gestured depiction. He begins this talk with the discourse marker “so”. When he utters “So” his hands spread and begin to lift off the table.



Figure 6.2. Hands prepare to create depiction

The use of the word “so” with the lifting movement of his hands signals to the recipients that an upcoming gestured demonstration is coming. As Bram continues with “if you had like two regions” his gaze shifts to his building hands. The fingers of his one hand begin to slip laterally in between the fingers of the other. As he performs this action Bram continues with “that were like that”. His fingers are fully interwoven with one another as he lifts the form into the vertical dimension and presses the gestured depiction into the shared interactional space at the very moment he utters “that”. Raya and Ellie’s gaze lifts with his hands (see Figure 6.3).



	
1. BRAM: ...if you had, like, two regions	2. that were like that (.) and then
<i>Bram interweaves fingers of both hands. Gaze drops to his hands.</i>	<i>Bram rotates gestured image to vertical. Gaze goes to participants.</i>

Figure 6.3. Bram presents the gestured depiction

The “interwoven hands” depiction has effectively gained the joint attention of the recipients as evidence by their direct gaze to Bram’s hands. This has been achieved through the practice of modeling and the timely and ordered coordination of talk, gaze, and space. Next, I look closer to the practices and elements used to construct the depiction to show that successful introduction of the depiction is bolstered by the sequential partnership of the talk, gaze, and motion of the hands in space. I round back to the same sequence of talk and action and examine the coordination of these elements more closely to show how one element supports the next.

The direct presentation begins with the talk “so”. The talk comes during the preparation of the hands for achieving the completed depiction. By the talk preceding the completed gestured depiction, the talk acts as a stage one marker signaling to the recipients that a demonstration is upcoming. Ellie’s head nod on the heels of Bram’s utterance of “so” indicates her attentive awareness. Subsequently along with “so”, “like” further signals an upcoming demonstration (Streeck,2002). This signaling in talk to organize recipients’ attentional posture is strengthened by Bram’s gaze to his preparing

hands as he speaks. The gaze to the hands adds further information for the recipients that the impending information is going to be delivered through his hands. As a result of the signaling tools of (1) the use of the words “so” and “like”, (2) the gaze to hands, and (3) the gestural move to lift the hands, Raya and Ellie respond with direct gaze to Bram’s hands.

The advancement toward the completion of the “interwoven hands” depiction continues with the second use of the word “like” followed immediately by “that”. As Bram utters “like that”, he simultaneously lifts his focus off his hands and shifts it to Ellie and then Raya as he rotates the gestural shape from a horizontal positioning to a vertical one. He lifts and presses the completed gestured depiction into the shared interactional space. At this moment the gestured depiction has solidly assumed the stage and has achieved full attention from its audience. The communicative accomplishment is that Bram’s interwoven fingers depict a physically improvised model of “two regions” that demonstrate the “ideal sort of structure” needed to achieve electron transfer.

The careful building and strategic coordination with talk, gaze, and action do more than just present a depiction to communicate a concept. It also functions to organize and define the interaction. (1) The hands have been enrolled as the medium and material for the construction of a tangible depiction for explanation, and have been recognized as something worth attending, as evidence by mutual attention to the hands as artifact. (2) Immediate roles have been defined and assumed through the use of the hands and body in partnership with talk. Bram is, in this turn, the expert sharing information and Raya and Ellie are learners expected to take in the information through action and talk.

Step 2: Adding elaborations. Once introduced and recognized as a participant in the explanation, Bram uses the “interwoven hands” depiction for adding finer elaborations to the concept. For instance, he adds the importance of the location of electrodes for achieving energy. He does this through the coordination of talk and gestural activity over the already-built gestured depiction.

As Bram states “...and then have an electrode up here and one down here, that would be somewhat ideal”, his right hand drops out of the just-built construction and takes on the role of a referencing agent. His right hand moves above the left hand that maintains half the shape of the “interwoven hand” depiction as he says “up here. His right hand then moves below the stabilized left hand as he utters “down here”. Finally, his right hand slides back into position to return to the complete “interwoven hands” depiction as he finishes the statement with “would be somewhat ideal” (see Figure 6.4). All the time during this process of adding elaborations, Raya and Ellie’s gaze remains resolutely on Bram’s hands.




		
3. BRAM: And then have an electrode up here	4. and one down here	5. that would be somewhat ideal
<i>Right hands references above left.</i>	<i>Right hand references below left.</i>	<i>Right hand slips into left.</i>

Figure 6.4. Bram adds elaborations to gestured depiction

Taking on these practices of referencing to add detail sometimes means breaking down the depiction from its full form, especially when two hands create the depictions. In this example, Bram has to drop out one hand in order to reference location. He

recuperates the break down when he returns the referencing hand to complete the full depiction.

At times referencing can happen without dissolving the entire shape but only compromising it when two hands are needed to make the depiction. When Bram states, “You absorb light in this material” he shakes his left hand, pulls it slightly out of its interwoven position with the right hand. The right hand remains poised in a loose representation of the shape it takes in the gestured depiction. He begins the statement, “You’re close to the other material”, and accents his right hand with a pulse as he says, “you’re”. As he finishes out the talk he settles the referencing hand back into the full gestured depiction (see Figure 6.5). Once again Raya and Ellie remain focused on his hands.

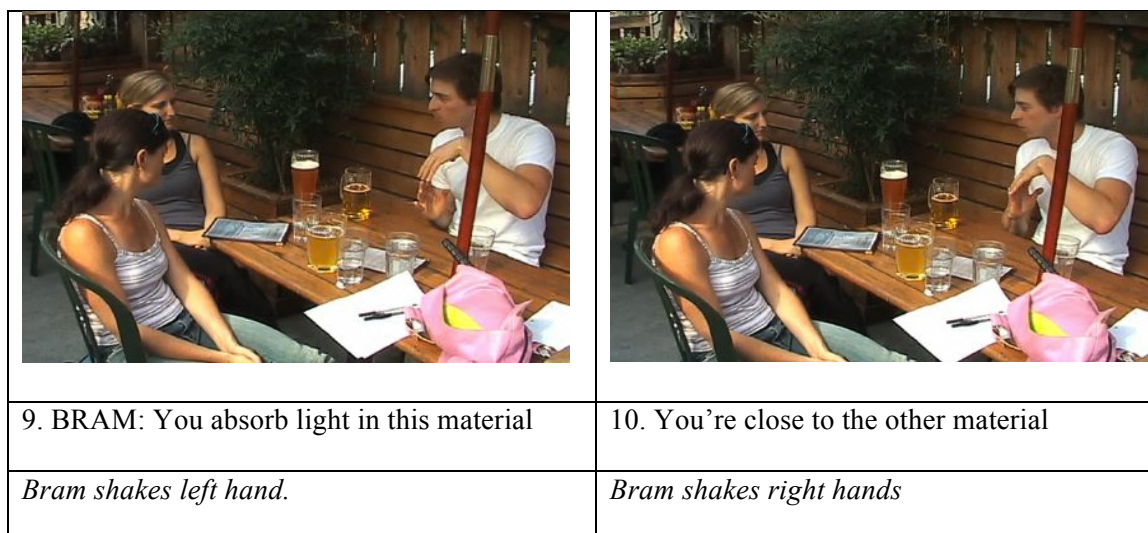


Figure.6.5. Bram references parts of gestured depiction by shaking his hand

In both instances presented, as a result of the move to return to the complete and whole gestured depiction, Bram has managed to make use of the affordances of the hands for depiction and bridge the constraints. As one hand slips out of the role of modeling to reference a part, the complete image is sacrificed. A return to the modeling of the whole

image encourages the image, to persist. Bram's choice to return to the complete "interwoven hands" depiction after borrowing a hand to reference details expresses a skillful pattern for keeping the gestured object present. He sandwiches depictions for referencing in between depictions for modeling.

As revealed in this last sequence, multiple practices for depiction can occur simultaneously. But they must be crafted in a way that allows for the successful accumulation of information. Bram continues skillfully through these practices of modeling and referencing and adds the practice of tracing and enacting.

As Bram adds information in talk ("It [the electron] hops over and then transfers down"), his hands offer information in action. The right hand stands to hold the place of the full "interwoven hands" depiction as the left hand drops out to assume other explanatory functions. The left hand steps out to trace out a pathway as the finger points to one place on his hand, then another, and finally traces out a downward pathway towards his wrist as he says "transfers down" (see Figure 6.6). But the left finger is doing more than tracing out the pathway. Besides acting as a pointer to reference the pathway, the finger is also being the electron as it enacts the electron behavior. His finger, like the action of the electron, "hops". (This is further supported by the finger-as-electron with the referent "it" in "It hops over...").

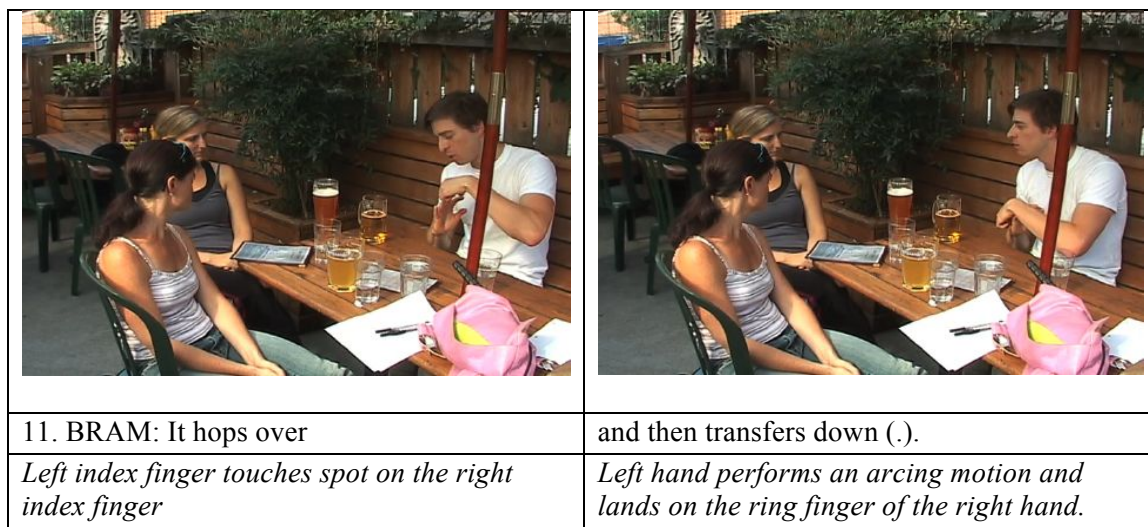


Figure 6.6. Depiction practices move from modeling to tracing to enacting

Gestural practices for successfully depicting a concept cannot exist independent from one another. Practices for depicting (modeling, referencing, tracing, and enacting,) work together and feed off one another to communicate a complete statement. The complete statement Bram's talk and varied actions achieves is a complex, multi-tiered statement that is only whole if delivered in context of talk and gestural practices that deftly slide across modeling the thing, referencing parts, tracing out pathways, and enacting the electron. The entire statement, although brief (consisting of only 7 words) in terms of the time it takes up, expresses a great deal of information. The talk and gesturing, communicate (1) that the electron needs to be close to the other material to retain enough energy from light absorption to make the transfer, (2) and that the electron "hop" happens by virtue of being positioned in a particular relationship to the material.

Here exists an example of the symbiotic relationship of talk and gesture to communicate an idea fully and efficiently. It becomes a narrated, visual, kinetic animation that delivers complex information succinctly and effectively demonstrating the

pragmatic thrust of multiple and simultaneously employed resource and depiction practices that move across modeling, referencing, tracing, and enacting.

Segment 1 has shown that Bram's building of the gestured depiction is a step-by-step process fashioned for his recipients, and this requires the coordination of gaze, talk, and gestures. It also requires the careful crossing of practices for depiction that include more than modeling but referencing, enacting, and tracing. It is not simply that Bram presents a gestured depiction that achieves his recipients' attention. It is how he presents this gestured depiction. His manner of construction manages to capture and sustain his recipients' full attention as evidenced by their continued gaze to his hands. Next I show that Bram's achievement of making use of the gestured depiction is, in part, due to his awareness of his recipients' attentional orientation.

Co-construction: The building of the depiction is shaped by the recipients' actions. Building a gestured depiction for recipients also involves making choices based on the recipient's actions. At first glance, Bram's building appears to be an animated monologue as Bram sequentially builds the concept with the gestured depiction step-by-step and with the recipients in mind. A closer and more extended look, however, shows that there is a very active dialogic component that shapes and directs the Bram's building of the gestured depiction to communicate the concept.

I return to the talk and action just analyzed as well as to the 4 units of talk and action that precede the presentation of the gesture depiction. I view the talk and action with a concentration on the use of and attention to gaze as an immediate building block in the process of constructing a gestured depiction for recipients. I show how a maker's

building is not an independent process but, in fact, a process that is determined by the moment-to-moment talk and actions of all participants.

Successful highlighting of gestured depiction requires preparation. To illustrate that successful highlighting of a gestured depiction involves preparation, first I attend to the talk and action prior to the presentation of the “interwoven hands” depiction.

“The ideal sort of structure”

- | |
|---|
| <ol style="list-style-type: none"> 1. So the ideal sort of structure that we can think of 2. would be if you could mix it. 3. Have the 10 nanometer separation but have 4. Ahhh interconnected pathways |
|---|

Figure 6.7. Transcript of talk

I examine the recipients’ attentional behavior as a resource for Bram’s planning of how to highlight the depiction as something essential to the explanation. Bram makes choices for the use of resources to build his depiction for his recipients based on the actions of others and in service of his interest to convey information long before he presents the “interwoven hands” gestured depiction. I pay particular attention to the use of gaze.

Bram begins to set the stage for the presentation of the gestured depiction in the 4 units of talk that precede the gestured depiction’s debut. Bram’s uses his gaze and his recipients gaze to establish fertile ground for a successful initial presentation of the gestured depiction.

Bram’s prelude to the presentation of the gestured depiction of “two regions” starts with gaze directed to Raya with the speaking of “so” and a shift of gaze to Raya on the word “the” (“So the ideal sort of structure that we can think of”). Ellie instantaneously responds to Bram’s attention, organizing her gaze by extending her posture upward and slightly forward and directing her gaze to Bram. Bram’s first glance to Raya, however, finds her visual attention elsewhere, catching her while she sinks in

her chair and lifts her hand to scratch her lip. In this one gaze pass Bram is able to discern his recipients' attentional orientation as communicated through their posturing. He has earned Ellie's attention but not Raya's fully.

In response to this awareness, he commits his gaze back to Raya. As a result, Raya resumes her attention to him. By the next string of talk ("the ideal sort of structure") he has achieved both their visual attention as Raya and Ellie indicate their heads toward Bram. Ellie follows up with a confirming nod as Bram says "sort of structure", further demonstrating her attentional presence. Bram designs his next turn in response to Ellie. He shifts gaze off Raya and to Ellie as he continues with "we can think of" (see Figure 6.8).

His alternating gaze between recipients becomes a building tool that is enacted based on Bram's evaluation of his recipients' attentional level as demonstrated through Raya and Ellie's posture and gaze. This gives evidence that Bram's gestural activity for explanation is an interactive endeavor this crafted moment-by-moment out of the perceived needs and involvement of his recipients.




		
<p>1. BRAM: So the <i>Bram's gaze moves from Raya to Ellie. Bram's focus is on Raya. Raya's gaze is in distant space.</i></p>	<p>ideal sort of structure <i>Ellie and Raya respond to request to gain attention and gaze to Bram.</i></p>	<p>we can think of <i>Ellie nods. Bram's gaze is maintained on Ellie.</i></p>

Figure 6.8. Bram uses gaze to organize his recipients' attentional orientation

In the talk and action that closes this segment Bram makes the choice to use his gaze to maintain an interactional connection. Bram lifts his right hand as he utters, “ahhh interconnected” and slides his hand laterally across the space. His gaze remains stable on Ellie (see Figure 6.9) never attending to his gesturing hands that moves in periphery space of the interactional stage.



Figure 6.9. Bram's gaze secures recipients' attention

Bram makes the choice to his use gaze to secure the recipients' attention rather than highlight the gesture that merely acts as a restatement of talk. The gesture is treated as not essential to the talk. First, there is no gaze shift to his hands. Second, the gesturing, although visible to the recipients, happens in his peripheral space. Finally, the talk and action are out of sync. (The gesture dissolves before the talk is complete). Such practices suggest the gesturing is not intentionally crafted to be selectively communicative. (It is likely helping to plan his talk).

I suggest that Bram's choice as he says "ahhh interconnected pathway" to use his gaze to establish an interactional rapport over-rides the need to use his gaze to direct recipients to his hands at this point. (The hands are not providing any more useful information than the talk is). Thus, he does not expend energy to highlight the gesturing here with such practices as gaze to his hands. He instead uses his gaze to achieve an eye-to-eye connection, giving preference to the need to use the gaze to focus on recipients rather than to focus and highlight his hands.

I circle back to the moment of talk and action where Bram presents the "interwoven hands" depiction representing "two regions" and compare the previous use of gaze to use of gaze here. By the time it is crafted, Bram has invested the groundwork to insure the "interwoven hands" depiction is treated as the most valuable part of the explanation. His hands, previously at rest on the table, lift to occupy the central space. His gaze slowly drops off Ellie and to his hands, acting as invitation for his recipients to follow his gaze. Both Ellie and Raya do exactly this. They adjust their gaze directly to his hands (see Figure 6.10). With the strategic use of gaze to direct attentional orientation, the "interwoven hands" depiction has assumed central importance. At this point all participants are intently focused on Bram's hands depiction of "two regions", illustrating the collective achievement of attention to the hands as critical information for concept building.

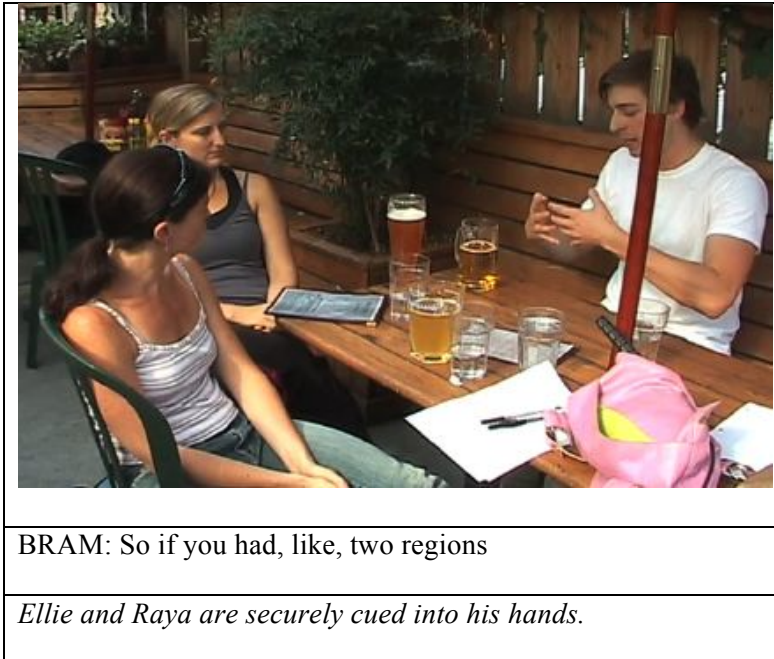


Figure 6.10. All participants gaze to gestured depiction

The analysis suggests that Bram makes choices about how and when to employ practices in order to set up his recipients' visual attention to what he deems as most important – the gestured depiction.

Sustaining attention to the gestured depiction. As Bram has succeeded in gathering interest to his hands as he presents the “interwoven hands” depiction, he continues to craft practices and elements for depiction in response to his recipient to sustain their attention. He pushes the gestured depiction into the interaction space, more toward Ellie than Raya. Ellie’s presses her head towards his hands and then Ellie nods (see Figure 6.11). Her actions communicate to Bram that her attention to the gestured depiction has been achieved.



	
5. BRAM: So if you had like two regions <i>Ellie's gaze stabilizes on Bram's hands</i>	6. that were like that (.) and then <i>Bram rotates gestured image to vertical, presses it toward Ellie. Ellie nods again.</i>

Figure 6.11. Ellie confirms presentation of gestured depiction with a head nod

Raya's attention, however, is not completely locked in. Raya's gaze has waivered. Her body remains more passive as she sits back in her chair. She has not provided any confirming actions such as head nods or smiles. Rather she has furrowed her brow. After presenting the gestured depiction and as he continues on to add elaboration, he shifts his positioning of the gestured depiction and his gaze off Ellie and to Raya (see Figure 6.12).



	
7. BRAM: and then have an electrode up here.	8. and one down here
	<i>Ellie's gaze to Bram's hands. Bram adjusts gaze and depiction toward Raya.</i>

Figure 6.12. Bram adjusts gesture depiction for Raya to see

The slight torque in Bram's body not only indicates a shift in the availability of the depiction for Raya, but also demonstrates an interactional move that aims to achieve

the interest of gaining Raya's understanding by securing her attention. Throughout the rest of the talk Raya pulls gaze from Bram's hands, gazes to Ellie and back to Bram's hands again. Such action may suggest to Bram that Raya's attention is still tentative. As a result, Bram's gaze remains resolutely on Raya.

When Bram concludes talk, he holds the space for a moment with the gestured depiction and then releases his hands, keeps his gaze on Raya, then folds his hands into one another, still keeping gaze on Raya (see Figure 6.13).



Figure 6.13. Bram's hands come to rest when talk concludes

This analysis has illustrated that a speaker makes choices to organize and position participants for the presentation of a gestured depiction that he deems central to the explanation. The choices are informed by the recipients' attentional behavior. This suggests that the activity of building a gestured depiction that intends to serve the explanation is not an independent activity. Rather, it is a collective one that is made up of an interaction between a maker's and recipients' embodied actions

Conclusion: What has been gained from the analysis? Episode 1 further confirms a pattern for presenting a gestured depiction for the benefit of the recipient. It is a step-by-step building that begins with full presentation and continues on with the addition of elaborations. This analysis shows that an explainer building a gestured depiction for the use of communicating a concept in explanation orchestrates the building process based on the recipient's attentional behavior, and what he deems as most valuable to the explanation. This gives further insight to the claim that it is not enough to simply bring gestures into an interaction. Their construction needs to be carefully crafted. The crafting thus becomes a co-collaborative event that happens in response to moment-to-moment changes. In considering the use of gestures in teaching and learning situations, we need to not simply attend to the presence of gestures, but also need to attend to how instructors bring gestured depictions into being to achieve desired goals.

Episode 2: Learners Enroll the Gestured Depiction and Use it in Multiple Ways. The last episode closes with Bram opening the floor as his talk concludes and hands come to rest. Episode 2 begins with Raya immediately taking the floor. Raya creates the gestured depiction in her own hands. The take up shows that she not only accepts the gestured depiction as a part of the explanation, but uses it to further her understanding.

“I didn’t quite get this?”

- | |
|--|
| <ol style="list-style-type: none"> 1. RAYA: I didn't quite get this. 2. Did you follow that? 3. ELLIE: I think so. I think so |
|--|

Figure 6.14. Transcript of talk from Episode 2

In the short segment that makes up Episode 2, I call attention to how the gestured depiction . undergoes multiple functions across a 6 second use of the depiction as it

morphs dynamically across being a resource for (1) thinking, (2) communication, and (3) interaction. The gestured depiction tactfully slides over and across functions depending on the needs of the participants, the contingencies of the interaction, and the availability of other resources. As a result, the depiction ends up being a resource, not exclusively “for me” or only “for you,” or “for us”, but performs all function in one short instance. For analysis purposes, I divide this segment into three stages of gesture use to show with detail the gestured depiction’s flexible and dynamic nature as a poly-functional resource.

Stage 1. Raya first loosely produces the gesture “for her” as a depiction to support her thinking. In a pause in between turns, Raya slowly alters her focus from Bram to Ellie. As she does this she lifts her hands off her lap, keeping them in her near space. The two hands hold a shape with spread fingers and open palms. Not quite completing the “interwoven hands” depiction until she settles her eyes on Ellie and completes the utterances, “I didn’t quite get this” (see Figure 6.15)



1. RAYA: 1. I didn’t quite get this.

Raya begins to create gestured depiction. Gaze moves from Bram to Ellie.

Figure 6.15. Raya prepares to create gestured depiction

The depiction is tentatively performed. It is loosely made and it resides close to her own body. There is a misalignment of talk with the depiction. (The depiction is not yet tightly formed when she says “this”). This stage of the rebuilding is “for Raya”. As Bram’s depiction was immediately (1) aligned with talk, (2) performed firmly, (3) and presented in the recipients’ sightline, his practices intentionally solicited the attention from his recipients, positioning the gestured depiction in a communicative role. This is not the case with Raya’s gesturing in Stage 1 of the reproduction. Practice and elements of the gestured depiction in Stage 1 suggest the depiction is for thinking. It is for a stage of thinking that is about organizing new knowledge and to bringing it to talk.

Stage 2. Once complete, Raya uses the depiction to enroll Ellie. Raya, now having achieved the complete form of the “interwoven hands” depiction, voices to Ellie, “Did you follow that?” Hands lift higher as she says “that” (see Figure 6.16)



2. RAYA: Did you follow that?

Raya creates gestured depiction.

Figure 6.16. Raya presents gestured depiction

With the depiction in hand, Raya torques her body and inclines toward Ellie and away from Bram. The depiction now resides in the space between Raya and Ellie. The

use of the indexical term “that”, a shift from “this” when the depiction was nearer to Raya’s own body, suggests that depiction is connected to her talk that is meant for Ellie. Ellie responds, “I think so. I think so”.

The presence of the gesture in Raya’s hands represents something slightly different than when in Bram’s hands. For Bram it is meant to be an improvised model of “two regions” of material displaying “an ideal structure” for electron transfer using energy from the sun. For Raya these refined aspects of the concept collapse into the same gesture but do not hold the complexity of meaning as it does in Bram’s hands. Raya’s depiction, although a morphologically similar copy of the entire gestured depiction, is, rather, a non-specific, conceptual reference to the entire stream of explanation just shared. So from Bram’s hands to Raya’s hand the gestured depiction slips from being a concrete representation of an established idea to an abstract conceptualization of an idea not yet fully understood. Ellie’s “I think so” then is in response to a gestural depiction loosely partnered with talk that does not invoke detailed aspects of polymer cells, but rather more generally references the entire stream of explanation.

The depiction serves as an efficient short cut for communication. As a result of not fully understanding the nuances of the concept, using the hands to depict the entire talk is an economical as well as strategic move for Raya. The hands hold all the talk previously shared and allow Raya to just present the image and not exert the work to find the words and use the time to put into words, words she likely does not have yet. This is an example of the one of the critical affordances of gestured depictions in of face-to-face

arrangements – the depiction can quickly render and efficiently communicate ideas difficult and time consuming to put into to talk

As a result of the depiction being used to stand in for the entire stream of explanation in order to communicate to Ellie, it is also deftly used to assess where her co-learner is in the process of understanding. When Raya says, “Did you get that?” she uses it to check in with Ellie to see if she is either with her in need for more clarification or for her as someone who can offer more illumination as the discussion moves forward. Raya’s use of the depiction to check in with Ellie helps establish Ellie’s future role as a resource available to Raya to gain clarification she needs. Ellie’s confirmation with “I think so” also confirms her as a possible resource for clarification (as will be realized in the turns to come). As a result, the depiction also becomes an interactional tool to assess and define her co-learners role in her developing understanding.

Stage 3. In Stage 3 of the reproduction of the gestured depiction, the depiction becomes a direct request for information from the expert. Raya pushes the fully completed “interwoven hands” depiction squarely in to the shared interactional space, placing it in the participants’ sight lines. Her right elbow lifts to frame the depiction. She re-orientes the depiction so it is vertical, one hand above the other (see Figure 6.17) (mirroring Bram’s depiction more precisely). She says, “So this is 10 -”.


	
3. RAYA: So this is 10-	This isn't the 10 nanometer that -
<i>Raya shakes right hand.</i>	<i>Raya completes gestured depiction as her gaze shifts to Ellie.</i>

Figure 6.17. Raya uses depiction to gain clarification

She cuts her own talk off as she maintains the depiction in the central space. She then proceeds to pull the right hand slightly out of its gestured depiction formation. The left hand remains stable. She shakes the right hand, still maintaining its form, as she resumes with more elaboration, “This isn’t the 10 nanometer that-”. In this action sequence, the hands still assume a modeling role but the right hand simultaneously adds a referencing action with the shake. Her gaze shifts to her hands on the shake and then moves over to Bram once she cuts off her own talk again.

The depiction is meant for Bram in order to achieve clarification from the expert. The practices and element for depicting here include, (1) referencing by shaking the hand, (2) alignment of talk with the gestured depiction as this coincides with the shaking of the right hand, (3) gaze to the gesturing hand and to then recipients to establish mutual orientation, (4) and positioning the gestured depiction in the interactional space and in the sight line of the recipients. The gesture thus becomes an overt bid for clarification of the properties of the gestured depiction.

By the time Raya's depiction reaches Stage 3 it has strong similarities to Bram's. Hands are lifted; participants' gaze is to the hands. Directly aligned references of demonstrative pronouns such as "this" in "this is the 10" resemble Bram's use of "that" when he presents the depiction for the first time. Such use of language with the gesture indicates the depiction is meant to be seen. Although practices appear to be similar to Bram's, its use in the interactive explanation is quite different. Bram uses the depiction to communicate, as does Raya. Bram, however, is communicating a concept that he understands. The nature of Raya's communication is not a reporting out of understood aspects of the concept but rather a demonstration of how she is thinking about the concept in the process toward understanding. The gesture, certainly a depiction for communicating, is, more precisely, a depiction for communicating *her thinking* in a process for gaining clarification from the expert.

Conclusion: What is gained from the analysis? Episode 2 reveals that gestured depictions carefully built by the expert for the recipient are taken up by the learner (so much so that Raya repeats Bram's practice of referencing through shaking the hands to highlight an aspect of the full depiction). Raya's immediate take-up of the gestured depiction shows that she has recognized it as central to the explanation of the concept, affirming that Bram's building was successful. This is significant in itself. What is more revealing than identifying that the gestured depiction travels from Bram-as-explainer to Raya-as-learner is distinguishing between how the same gesture, in its relative form, is employed to serve different and changing functions to achieve the shared goal of explanation and understanding across the one, very short, instance of the same gesture in use.

This short example suggests that gesturing can be used for a mixture of purposes that fall in between being strictly “for you” or solely “for me.” This adds to the general focus of studies that examine gestures as either primarily communicative or dominantly used for thinking. Gestured depictions in interactions are multi-taskers, as the data is expressing. They gracefully slide over and across functions depending on the needs of the participants, the contingencies of the interaction, and the availability of other resources and end up as serving as resources, not solely “for me” or only “for you,” but also “for us”. This finding is in important as it reveals

Episode 2 also characterizes gestured depictions as not only artifacts, but also as actions. Actions that, in turn, craft subsequent actions. For example, as Raya presents the depiction to represent her thinking to Bram, it also works to define Bram’s next action – to answer the question. In the turn to follow, represented in the next episode, Bram takes up the depiction and offers Raya’s clarification through talk and gesture.

Episode 3: People Work Out Ideas Together Using the Gestured Depiction.

In Episode 3 I show that gestured depiction mediates the interaction process as people work out ideas together and across ways of experiencing the gestured depiction.

Episode 3 is the immediate follow up of the talk and action that concludes Episode 2. Its beginning is marked by the change in turn as Bram resumes the gestured depiction in his own hands to attend to Raya’s bid for clarification.

“Well think if this finger”

1. BRAM:	[Well think] if this finger
2.	was like 10 nanometers thick, ahhh, pa ahhhh [rod or some]thing
3. RAYA:	[OK. Uh huh.]
4. BRAM:	in [space].
5. RAYA:	[OK}
6. BRAM:	So you have, you have the material, the ma- , the plastic that [absorbs light]
7. RAYA:	[Right].
8. BRAM:	and it has this excited electron on it
9.	and [right next door] to it
10. RAYA:	[Oh. I see]
11. BRAM:	and then (.) then on [this material]

Figure 6.18. Transcript of talk from Episode 3

Gestured depictions are passed back and forth between participants to produce understanding together. In Episode 3 the depiction moves across participant to develop understanding. It is not a guided process of discovery where the gestured depiction is passed orderly back and forth to facilitate a learner’s own discovery. That is, Bram is not trying to get Raya to uncover the answer on her own, a strategy for teaching that often shapes classroom interactions. He proceeds not in the vein of teacher with a pedagogical intent, but rather more as a conversant trying to figure out what his interlocutors need and then delivering it. This difference, although at first appearing to be a minor point, is in fact the very premise that shapes how Raya, Ellie, and Bram engage gesturing in a back and forth exchange that shapes a collaborative discursive journey toward understanding.

In the example with Mara and Steph from Study 1 the gestured depiction is orderly passed back and forth, each turn a direct accumulation toward understanding. This kind of exchange can be likened to a tennis game where the gestured depiction gets volleyed back and forth between players as it moves in an orderly manner from one side of the court to the next until “the play” is accomplished. These next examples are different. They can be likened to a dance rehearsal where a choreographer moves among his dancers improvising movement phrases as the dancers attentively follow along trying

to capture as much of the information in as many ways as possible. Raya and Ellie, like dancers trying to learn a new phrase to be repeated later, pick up the new information through multiple perceptual processes that include watching and intermittently copying parts of the phrase. This perspective for analysis adds to the idea that not only do gestures emerges as a product of the process of interaction (Goodwin, 1979; Streeck 1994), but also how the collaborative action is played out influence how gestures function in the interaction.

As Raya concludes her question, there is a slight negotiation to determine who will take the floor, Ellie or Bram. The floor is assumed by the pick up of the gestured depiction. Ellie unsuccessfully attempts to take the floor as she creates the gestured depiction (see Figure 6.19). Her hands lift and then immediately fall to her lap when Bram lifts his hands (see Figure 6.20).



(No talk)

Ellie starts to make gestured as Raya concludes her question.

Figure 6.19. Ellie attempts to take the floor with the depiction

Now in Bram's hand, the depiction becomes a communicative tool to clarify Raya's understanding. While Raya holds the gestured depiction in its entirety, Bram only picks up half of it (see Figure 6.20) to add an elaboration to help answer her question. Bram does not need to reproduce the entire shape. Not only has it been established as central to the explanation, Raya's hands are also acting to stabilize the depiction as Bram focuses on its parts. Here is an example of the how coordination between gesturing participants allows the depiction to persist in more detail as concepts gets worked out together in the interactional back and forth.

5.BRAM: [Well think] if this finger was	like a 10 nanometer thick
<i>Raya holds entire depiction while Bram produces half of it.</i>	<i>Raya mimics Bram and touches her finger.</i>

Figure 6.20. Raya and Bram both create depiction

Raya uses her hands and Bram's hands to think through the information. As she maintains the depiction in her hands her gaze goes to Bram's hands. This not only suggests that she knows the clarifying answer to her question will be performed in Bram's hands but also that the information needs to be transferred in her own hands. As Bram's index finger and thumb of his left hand touch the ring finger of his right, he says "like a 10 nanometer thick". Raya picks up Bram's actions. She touches her finger while he touches his finger. This action of touching her finger reveals that Raya

understands that the salient point made with the gesturing hands has to do with the width of a finger as an anchor for measurement.

An entire depiction can break down in order to highlight such elaborations inherent in the whole without losing the notion of the complete form. Although we have seen this phenomenon before, at this point in the explanation it not only demonstrates a balancing of practices to communicate, it also suggests a more advanced position of the gestured depiction collectively accepted as part of the explanation. Raya does not carefully return to the image of the whole depiction once she breaks it down as Bram did. She does not need to. This is important to note because it shows how the gestured depiction becomes an embedded actor in the interaction, able to seamlessly take on half forms to refer to the whole without breaking the flow of the explanation interaction.

When the gestured depiction is volleyed back to Raya, she keeps it for herself and makes it her own. She recreates the image in her own hands, looks to her own hands and confirms understanding with “OK. Uh huh” (see Figure 6.21) while gazing to her own hands.



Figure 6.21. Raya creates depiction to integrate new information

The slight pulling inward of her body to create her own frame around the gesturing, and her drop of gaze to look to her hands to compare her shape to Bram's identifies the current function of the depiction as a thinking tool for Raya. Raya is using the depiction to locate the elaboration about the ten-nanometer separations within the full depiction in her own hands and to anchor the new concepts as her own. The reproduction, then, is an intentional replication of a demonstration of an enactment of a concept that she takes ownership of and uses to make sense of the information in her own hands. On the communicative-thinking continuum, this gesture is exclusively for Raya. It belongs to her and is used for her.

In summary, this example illustrates that the gestured depiction moves back and forth between participants and in the process of its transfer it assumes multiple roles that roll toward the achievement of the intended interests of the participants. Raya's sufficient building, partnered with her confirming utterances, followed by the dropping of her hands to her lap as she utters a final "OK" with more certainty and closure than the ones that

preceded, give the impression that she is following Bram's explanation. Bram's next move to push on in the explanation shows that he deems Raya's understanding, as evidence through an orchestration of a confirming head nod, an articulated 'OK' and a sufficient presentation of the concept in her hands, to be adequate enough to be able to move on.

The depiction is a multi-tasker and at the same time it also shapes the ongoing interaction and the roles people play in it. It is important to note Ellie's failed attempt to take the floor in response to Raya's question. She, as the more knowledgeable learner, tries to support Raya's questions. But, Bram is the expert here and as Bram steps in she retracts the hands as a tool to take the floor, and allows Bram, the expert, to respond to Raya's question, solidifying the roles of Bram as expert, Ellie as learner "getting it", and Raya as learner in need of more explanation.

As Raya moves between watching Bram's hands to creating the same action in her hands and taking focus to her depicting hands, it raises the question of how gestured depictions are experienced by the recipient in the process of learning.

The gestured depiction is part of a multi perceptual journey to understanding.

Gesturing offers an interesting perceptual conundrum. Indeed, anytime a gesture appears in one's hands it is, by its nature of being made with the body, experienced in the body. The action can be defined as incorporated. That is as ingested by the body as a physicalized experience felt from the inside out. The entire body reverberates with sensitivity to the shape and motion in the hands. As a dancer I have learned to know the difference between bodily actions that reside in the body and those that still exist on the outside of my body but yet created on my body.

Accepting that perceptual engagements with gestured depictions can range between visual experiences to visceral experiences (see Chapter 4 for a full review), I examine the data and show how the recipients oscillate between using gestured depictions as a visual resource to be observed to using their own gestural enactment as a visceral resource, deeply incorporated in the body, to be felt. However, choices can be made to which perceptual experience the maker may preference and attend to. Gaze to the gesture indicates that the maker is using the hands as a visual resource. Gaze away suggests it is the felt experience that is being perceived in the body.

In the example to follow, the data suggest that Raya uses Bram's gesture as visual resource and then her own unique gesture as a visceral resource, partnering both experiences in her learning of a concept. Bram positions the depiction in the interactional space. He lifts his elbow to frame the gesturing hand, giving the impression it is something, once again to be attended (see Figure 6.22). The use of the word "so" signals that a demonstration is about to take place. All are practices and elements that, as I have shown before, define the gestured depiction as meant for the recipient. Raya and Ellie respond to this cue for their visual attention. Raya drops her hands to her lap and directs her gaze to Bram's hands. Ellie, having switched her gaze back and forth between Bram and Raya, stabilizes her gaze on Bram's hands as well (see Figure 6.22). Both recipients' actions represent the image of attentive audience members, showing they both engage Bram's depiction as a graphical representation as it transports information visually as they look to it.

Raya, immediately coming in on the heels of Bram's utterance about "plastic that absorbs light" performs a unique gesture (a gesture that has not yet been authored by the

explainer or the learner). She reaches forward with an open hand, grabs space in front of her and then pulls her hand inward as her fingers close. As she finishes the gesture she utters an introspective “Right!” (see Figure 6.22). I will refer to this as the “pull” gesture. The “pull” gesture animates information that adds elaboration to the gestured depiction that remains stable in Bram’s hands. It is Raya’s visceral enactment of the process of absorption of light that is happening in the material depicted in Bram’s hands.



	
<p>8. BRAM: So you have, you have the material, the plastic that absorbs light</p>	<p>9. RAYA: Right</p>
<p><i>Raya and Ellie observe Bram’s hands.</i></p>	<p><i>Raya extend open hand and then pulls toward body as she closes fingers to create fist.</i></p>

Figure 6.22. Raya and Ellie observe Bram’s enactment

What is of interest about this turn is that knowledge is undergone across two gestures created by two participants and engaged via two different perceptual experiences. The pull gesture is a visceral enactment performed by the recipient to add detail to the visual depiction maintained by the explainer. Here is an example that suggests that face-to-face explanations are not simply interactive events between people, nor are they interactive events because they include not only the people, but also the resources in the surround, such as the hands. They are also interactive experiences because ways of perceptually experiencing the gestured depiction also undergoes a progressive, interactive exchange between seeing with the eyes and experiencing in the

body. This phenomenon of the interaction between perceptual experiences allows for a collaboration across different ways of knowing with bodies in use.

Following, Bram continues on with talk and gesturing as Raya's hands come to rest and she resumes the position of audience observing the performance of his hands (see Figure 6.23). Her perceptual stance as observer, that is as "one who sees" continues to contribute to her understanding. She looks to Bram's demonstrating hands and voices, "Oh, I see".



	
<p>11. BRAM: and right next door to [it you have] 12. RAYA: [Oh I see.]</p>	<p>13. this other [material where it wants] to hop to 14. [I see]</p>
<p><i>Raya and Ellie observe Bram's hands.</i></p>	<p><i>Raya confirms her understanding as she watches Bram's hands.</i></p>

Figure 6.23. Raya and Ellie observe Bram's hands

Raya's realization that some knowledge has been filled (as suggested by "Oh I see") takes place at a defining point in the explanation. Bram concludes a long stream of talk that has repeated as well as added details to the full concept. As this information-filled segment comes to a close, Raya's use of "I see" is a poetic choice of expression of understanding. It serves two levels of affirmation. On one level she literally sees the concept that has been being constructed overtime depicted in the information rich

gestured depiction in Bram's hands. But "I see" may very likely be also referring to Raya's change in understanding. "I see" equating to "I understand."

What she likely "sees" (and "understands" as she gazes to her hands and feels their shape in her own hands is a composite coming together of all the discreet parts that make up the concept represented in the gestured depiction. She sees the (1) 10-nanometer separation as demonstrated by Bram's action of touching his finger (visually experienced) and copied by Raya (viscerally experienced). (2) The absorption process that is expressed in Bram's words and animated in Raya's gesturing (viscerally experienced), (3) and the proximity of the electron shown again through Bram's hands (visually experienced) and copied by Raya (viscerally experienced). Data suggests the possibility that when Raya lifts her hands and creates the depiction it serves as a confirmation and review of her understanding. All this was in part achieved by coordination of her visual and visceral experiencing of the information. This points to the provocative, yet not fully understood, relationship to perceptual experiences that happen in the world and in the body.

Gestured depiction can be used to change the course of the interaction. In this next example, I point out how the same gestured depiction that is used to communicate information and think through information is also used to change the course of the interaction.

Raya has been holding the gestured depiction on the edge of the interactional space while Bram finishes his last talk, which is a repeat of information she has already gathered. When Bram's talk concludes and his depiction begins to dissolve, Raya lifts the "interwoven hands" depiction higher and directly into Bram's sightline. She presses it

toward him and asks, “So is the direction important?” (see Figure 6.24). The depiction has achieves multiple actions. It is a depiction for Raya’s thinking, a depiction to communicate her thinking in a bid for clarification. It is an action that takes the floor. And it is part of an action that changes the course of conversation to support Raya’s current need of certain information. All together, this has changed the interaction, putting Raya in the driver’s seat with the gestured depiction acting as the steering wheel. Raya’s chooses to move the topic of talk to another idea, not yet discussed. It communicates the development of understanding of the concept this far and her move to now acquire elaborations emerging from her own developing understanding.

	
<p>14. BRAM: And then (.) then its on this material</p>	<p>RAYA: So is direction important?</p>
<p><i>Raya creates a copy of Bram’s depiction.</i></p>	<p><i>Ellie creates a copy of Bram’s depiction. Raya lifts hand.</i></p>

Figure 6.24. Recipients create depiction in their own hands

I return to my above interpretation that the hands are acting as a thinking tool for Raya and offer more evidence into how they act to support her thinking by focusing on how and why the question about direction emerges (“So is direction important?”). The idea of direction the material takes, whether vertical or horizontal, has not been brought up in talk. But it has appeared in gesture. In the process of her creating the gestured depiction (and experiencing it viscerally) she has created it in the both vertical position

and a horizontal one. She has only visually witnessed it vertically in Bram's hands. Perhaps the varied, repeated experiences of viscerally and visually experience the gestured depiction in both vertical and horizontal positions triggers a disparity that she brings forth for clarification – "So is direction important?"

Emerging from the data is a theory that the moving back and forth between these perceptual experiences, visual and visceral, supports a trajectory toward understanding. I suggest that the shift between the two perceptual experiences, a visual one where the gesture is engaged as a resource to be observed and a visceral one where it is experienced in the body, is a perceptual partnership that accumulates toward the development of understanding. The point is not that learners experience gestures as visual resources: they do. Nor is the point that learners experience gestures as visceral resources; they do. More specifically the point is that these perceptual experiences complement one another in a journey toward understanding.

To extend the discussion of gestured depictions as serving as instances of depictions to support individual thinking, I take a moment to concentrate on Ellie's making of the gestured depiction as represented in second frame of Figure 6.24. The gestured depiction is made without talk. Nor does its crafting demonstrates the practices that suggest it is meant for anyone else but Ellie. Ellie quietly and briefly performs the gestured depiction when no one is looking. As Raya raises the gesture to asks the question "So is direction important?" Ellie, at the same time, lifts the gestured depiction close to her own body and off to the side of the interaction space (see Figure 6.24). Her gaze goes to her own hands. It is direct and focused. The gesture is not highlighted for others to see or to use, nor is it accompanied by speech. It is attended to visually. For a

brief moment (less than 2 seconds) it seems to exist almost solely as a depiction for thinking that does not, nor intended to, enroll the attention of others. This is a private gesture for Ellie.

In her next move, however, a shift in practices changes the function of the gestured depiction from being a depiction to support her thinking and moves to an action to take the floor. Although the action is thwarted as Bram steps in to provide information to Raya's question, here is an example of the cross functional use of the same gestured depiction as it shifts from a depiction "for me" to a depiction "for you". This is important because it shows that the functional role of a gestured depiction is not defined within itself but rather in partnership with how it is performed in the world.

Conclusion: What has been gain from this analysis? Episode 3 continues to show that the depiction, now presented, is (1) developed step-by-step for and with the recipient as elaborations are added on. The gestured depiction continues to be (2) positioned and adjusted for the recipient. What is further revealed is the use of the gestured depiction (3) to correct and clarify the learner's misunderstanding and (4) that both the explainer and the recipients engage the practices for depiction that drive the interaction toward the shared goal of achieving understanding. Importantly, the data show that the gestured depiction is not simply treated only as a communicative artifact by explainer and recipient but that the gestures, in this predominantly communicative set up, can be employed to support both cognitive and communicative processes within the interaction. And finally, the data points to the interaction of perceptual experience of gestured depictions as a construction process that supports the development of understanding.

Episode 4: Gestured Depictions Evolve over Time and Across Participants.

In Episode 4 I show that gestured depictions evolve over time and collaboratively across participants, gaining more value across use. This is of significance in teaching and learning because once accepted as a shared association, the gestured depiction can be mobilized to activate further achievements in understanding. When the gesture depiction becomes infused with meaning and becomes something common and recognized among participants, it can be creatively and strategically used in more and varied ways that continue to drive the interaction and continue to advance understanding.

The episode begins at the point where Raya's question ("So is direction important?") is taken up by both Bram and Ellie. The episode represents a different teaching and learning interaction than what has occurred before. It is now more collaborative and explorative. Not that the gestured depiction been accepted as a metonym for the concept of polymer cell configuration, Raya and Ellie have begun to use it to expand further investigation on the concept. The interaction is an overlaying of talk and action by all participants. Understanding the role of the careful building of the gestured depiction in this evolution of teaching and learning is important when we consider how the role of the body in interactive explanation can be intentionally crafted for the effectiveness of explanation. The episode confirms that careful and collaborative building of the concept through the use of the body has earned the interaction a critical shared agent - the "interwoven hands" depiction. This shared agent becomes the mediator that allows the teaching and learning to reach a deeper level.

“So basically you are trying to control the material”

1.	RAYA:	So is the direction important? I mean-
2.	BRAM:	Yes
3.	RAYA:	It has to go, because if it was like this it has to go down?
4.	ELLIE:	[Because-]
5.	BRAM:	[Well] it has to] go toward the electrode, right?
6.	ELLIE:	So you have the positive electrode here
7.		and the negative one here.
8.		[Is that right?]
9.	BRAM:	[Either way] you want to think about it.
10.	ELLIE:	[{inaudible}] [something] There's one –
11.	BRAM:	For you to be able to use the electricity that is generated
12.		ahh the electrons have to go to one electrode
13.		and the holes have to go to the other electrode
14.		and they sort of travel in a loop opposite each other.
15.		That's what current is sort of defined as
16.	RAYA:	[Ok]
17.	BRAM:	the positive and [negative]
18.	RAYA:	[Like the flux] capacitor. [Heh, heh]
19.	ELLIE:	[Heh. heh]
20.	RAYA:	Sorry. Back to the future.
21.	BRAM:	So. Yeah. Yeah that's a good question.
22.		Why can't you like just have it ahhh mix
23.		that way and you need to consider those things.
24.		So the problem with that is that
25.		we have this idea but its really hard to realize, especially cheaply.
26.		Like we have ways that we think we can do it
27.		but they would cost way too much.
27.	RAYA:	So basically like yeah, you are trying to control how the material
28.	BRAM:	[Right]
29.	RAYA:	[spreads on this]
30.	BRAM:	Right

Figure 6.25. Transcript of talk from Episode 4

Learners use the gestured depiction for collaborative thinking. Now accepted as integral to the concept, the “interwoven hands” depiction mediates collaborative thinking among learners. I return to the moment where Raya raises the gestured depiction and ask if direction is important. This moment changes the interaction to be a collaborative “figuring out” where the gestured depiction becomes an agent for a new arrangement for the process of developing new thought. Ellie’s role changes. As set up as possible in previous turns, she now becomes a source of information for Raya’s understanding. Ellie’s private gesture for thinking, performed near her body, now emerges to become an

intentional public action collaboratively used by both learners to figure out the answer to the just posed question.

Returning to the conclusion of that last episode that bridges it to this new episode, we recall that Raya's hands, lifted high and framed by out-pressed elbows (see Figure 6.26) depicted her confusion is about whether the material needs to be in the vertical or the horizontal dimension.

Raya begins to try and answer the question herself as she shifts the depiction back to vertical ("Because if it were like this"). Its position in space, partnered with talk, solicits the visual attention (see Figure 6.26) from Bram and Ellie. The pause while Raya's shift the depiction from vertical to horizontal gives Ellie the opportunity to attempt to take the floor to offer her insight, perhaps, insight that emerged while examining the depiction in her private space.



	
1. RAYA: So is the direction important?	2. Because if it were like this (.)
<i>Raya presses depiction into the interaction space. Ellie recreates depiction close to her own body.</i>	<i>Raya represents horizontal position as referent for "like this". Ellie lifts depiction and turn body to interactional space.</i>

Figure 6.26. Raya uses the depiction to ask a question

Ellie and Bram begin to respond to Raya at the same moment. Ellie slides her previously private depiction toward Raya and lifts her gaze off her hands and toward Raya. As she begins to utter "Because", the talk overlaps with Bram's talk as he now

lifts his hands. Bram wins the floor but only long enough to create a brief image of the interwoven hands depiction as he says, “Well it has to] go toward the electrode, right?” The question opens the floor and Ellie steps in. Her hands now pass through the interactional space cross over into Raya’s space. She reaches her left hand over Raya’s depiction and begins to show reference where the electrodes are in relationship to the direction of the material configuration. Bram’s depiction begins to dissolve (see Figure 6.27).



5. BRAM: [Well it has to go] toward the electron

6. ELLIE : [So you -]

Raya maintains depiction. Ellie acts on Raya’s depiction. Bram references half the depiction in his own hands.

Figure 6.27. Ellie gestures over Raya’s depiction

As Elli continues her talk action, Raya’s hands drop out. (This is possibly to assume a position of observer, experiencing the depictions in Ellie’s hands visually) Ellie continues to gesture as if Raya’s depiction were still there identifying where the electrodes (see Figure 6.28).



6. ELLIE: have the positive electrode here
<i>Ellie references parts of the depiction as Raya maintains depiction.</i>
7. and the negative one here
<i>Raya releases depiction, sit back in chair, gazes to Ellie as she continues to add elaboration in the absence of the depiction.</i>

Figure 6.28. Ellie adds elaboration to Raya's depiction

Ellie's move to take the floor and to cross into Raya's space identifies a significant shift in the interaction. First, Ellie assumes the role, (a role that has been cultivated over the explanation) as more knowledgeable learner, providing insight to Raya's question. There is also a shift in how the gesture space is being treated and how the gestured depiction is being used. Up until now, gesturing has been performed in the shared interactional space and acted upon by either a learner or the expert. None have traveled into another's space to be worked on by both learners alone. This engenders yet another shift. The "figuring out" together becomes a process between the learners and not between the learners and the expert. This is an important alteration in arrangement because it allows new learners to negotiate information over a gestured depiction under the watchful eye of the expert.

With Ellie's move to cross the gesture boundary space she earns the floor. Bram releases his hands as material for the gestured and retreats slightly as he pulls his body away from the interaction space, giving her the floor. But the expert, although retreating for a moment while the learners think through together in the collaborative space, is not

outside the interaction for long. Bram is called back to confirm understanding when Ellie shifts the “interwoven hands” depiction in front of her and in Bram’s line of vision and ask “Is that right?” (see Figure 6.29).



Figure 6.29. Ellie confirms correctness with Bram

In synthesis, Ellie becomes a source of information for Raya through a process of using her body to take the floor and to depict the concept. She assumes the role by crossing the gestured depiction into the collaborative space. She steps into the role, not like the expert who communicates stable knowledge, but rather like an inquisitive learner in the process of developing understanding. She tries out the idea, making it visible for the expert, keeping him on deck for guidance. But she tries out the idea with and on her co-learner. This move defines the teaching and learning as a multi-party enterprise. It aligns Raya and Ellie not only as learners trying to understand the concept Bram explains, but now as learners trying to understand the concept together through the use of gestured depiction.

So far I have primarily highlighted gesturing that is essentially working to either directly depict a concept and gesturing that is used to think out information together in interactive arrangements. I have shown gesturing is either working for the recipient as it communicates stable and declarative knowledge or it is being used interactively for both the learners to communicate thinking, request clarification, and to work through new knowledge together. I have also shown how the gestured depiction acts like an orchestra conductor's baton and directs and shapes the interaction.

There are, however, gestured depictions that do not cleanly fall into these categories of uses. I pointed out a brief moment earlier where Ellie creates the gestured depiction and it is neither used to communicate thinking nor to ask a question. With close analysis, there are moments when gesturing in interaction appears to be intently for the maker and nobody else. The gestured depiction is born outside of the interaction. At first glance this seems to be an unusual and uncommon use of the gestured depiction in an interactive arrangement. Close analysis, however, shows that moments, when gesturing in interaction appears to be intently for the maker, are more common than not. I suggest that these brief, momentary gestures performed outside the flow of the interaction, are necessary gestures. These gestured depiction, as they are performed, are strictly for the learner and used to anchor and extend pieces of new knowledge. They, however, although very possibly unnoticed because of the briefness, seem important to the on-going learning. Following I examine such gestures in more detail.

Gesture in the hands of the learner can act like quick notes to record information in the body. I point to two more instances where both Ellie and Raya

perform gestured depictions that happen outside of the talk and are not highlighted for others. I suggest that these are pure thinking gestures for the learner.

In the following move, Ellie sets her beer down, and Raya reaches for hers. Ellie creates the gestured depiction in her near space and looks at it. It is not accompanied by talk nor related to Bram's talk (see Figure 6.30). Bram's gaze is to Raya. Raya's gaze is toward her beer. The gestured depiction is present for less than one second and no one gazes to it except for Ellie.



11. BRAM: the electrons have to go to one electrode

Ellie created depiction close to her body and gaze to her own hands.

Figure 6.30. Ellie “marks” the depiction in her near space

Raya demonstrates similar practices. In the move to follow, Raya sets down her beer and then creates the “interwoven hands” depiction briefly in her near space. She is the only one to gaze to it. (Bram's gaze is dropped as he starts to begin his next talk. Ellie's gaze is down as she finishes up her laughter in response to the recent joke). Raya's gestured depiction exists for less than half of one second. Once again, only the maker is intended to see the depiction (see Figure 6.31).



Figure 6.31. Raya “marks” the depiction in her near space

I identify this type of gestural action as “knowledge marked.” As learners reach a level of understanding, the depiction is no longer used only for “thinking through” information per se. It also begins to be used to ground newly acquired knowledge. I borrow the term “marked” from a practice in dance learning for grounding, reviewing, and noting information. It is not to be confused with the idea of marking in linguistics and discourse analysis. Marked here means an abbreviated or briefly present version of the gestural depiction meant for the maker. In dance, marking acts as a short hand, note-taking practice to review or ground knowledge of a movement phrase. Ellie and Raya appear to be using their hands here in a similar way – to note, review, and anchor all the information now held in the “interwoven hands” depiction.

These gestured depictions as defined as “knowledge marked” are slightly different gesturing practices for thinking than gesturing that gets performed in the process of working out concepts. They look the same but happen at a point in conversation after the

information is shared and negotiated. They happen at a moment when an idea is realized and parts of the whole come together. Much like the dancer who has just learned the movement phrase steps aside to mark out and record the information on her own in her own body, Raya and Ellie perform the gestured depiction outside the interaction and at the end of the discussion.

Now at this point the making of the gestured depiction, in their hands as their own representation, holds information for them both as a picture to view and as a visceral experience that is incorporated or filed in the body. The body is acting both as the material to create the visual as well as the container to hold the felt experience. I think of the hands in this case as acting as brief “notes.” And like notes scribbled in a notebook, revisits to such “notes” can trigger the larger idea. In a later situation, like a re-explanation, the “knowledge marked” gesturing for marking out information can act somewhat like the prompter sitting off stage cueing the actor with one word in order for him to recall the entire line. This is important to note because both Raya and Ellie are well aware that they, much like students who take a test, will have to share this knowledge later in a conversation with another.

As I keep stressing, gestures in interaction are never just “for me” or “for you” even when they appear so clearly to be so. They are more often than not also in service of the goal of the interaction. This is even true with the gestures as “knowledge marked.” Raya and Ellie both know they will share what they have learned in another conversation in two days. Much like the dancer who rehearses a phrase in a private space through hand marking, the learners seem to be using the hands to ground information to pull up later. Giving opportunity to a learner to ground information through performing

“knowledge marked” gestures, can contribute to transitioning understanding.

Understanding the role of these gestures can further inform how instruction designs can make use of these, hard-to notice, and yet important gestures for thinking.

Gestured depictions become charged with meaning as they develop over gestural rich extended explanation. Following I show that the hands as a medium to depict information have collectively undergone a kind of translation (Callon,1986; Latour,1996) in which a common definition has been proposed—hands are the material that represents the configuration for solar energy to evolve into electrical energy.

At the beginning of the explanation event, Bram creates a loose version of the gestured depiction as he says, “we have this idea”. It exists briefly and likely not registering as anything of important for Raya and Ellie as it has not become infused with any meaning. However, toward the end of the explanation event Bram says “this idea” again. He also creates the “interwoven hands” depiction in his hands again (see Figure 6.32). By now it has accumulated meaning to Raya and Ellie. It represents the “idea” as well as the mechanistic processes for construction and the chemical configuration for generating polymer solar cells.



BRAM: This idea...

Bram's hands come together into "interwoven hands" depiction.

Figure 6.32. The depiction stands in as "the idea"

Now as a shared and meaning-rich depiction, it is used by all to reference the entire concept. Raya uses it when she says "So basically like yeah, you are trying to control how the material". As she says "material" she creates a brief version of the depiction (see Figure 6.33). The depiction now holds not just the idea of "two regions" of material, but also the information of how "you are trying to control" the material. Everyone accepts this as so.

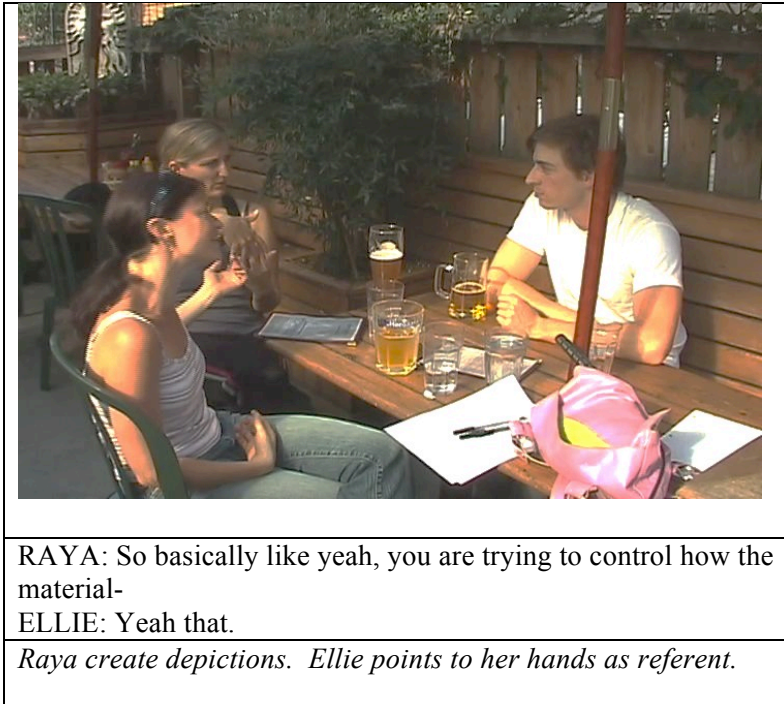


Figure 6.33. The depiction stands in as “the material”

In the next move when Ellie points to the “interwoven hands” depiction in Raya’s hands and says, “Yeah, that”, this again demonstrates that the depiction has assumed a shared meaning with a history - a meaning more easily expressed in the gesture than in the talk.

This use of the “interwoven hands” depiction as a shared and accepted representation of the entire concept proliferates later in the conversation. For instance, Ellie asks a question about the everyday utility of the concept and as she does, she raises her hands and presents the depiction. Bram clarifies that her question is about the material that slips into the spaces of one region to create an electron hop by referring to them as “these guys” (see Figure 6.34).

	
ELLIE: Where is this other material?	BRAM: These guys?
<i>Ellie creates depiction to “reference other material”.</i>	<i>Bram responds recreating depiction as he identifies then material as “these guys”.</i>

Figure 6.34. The depiction is referred to as “these guys” in Bram’s hands

Later, when Ellie asks another question, she creates the depiction and follows Bram and refers to them again as “these guys” (see Figure 6.35). The “interwoven hands” depiction has become so much part of the explanation that it earns its own personified identity.


ELLIE: Is it that “these guys”....
<i>Ellie creates depiction using the term “these guys” previously used by Bram.</i>

Figure 6.35. The depiction is referred to as “these guys” in Ellie’s hands.

These are examples that show that the “interwoven hands” depiction has been enrolled and mobilized as a significant member in the explanation. Its simple invocation in partnership with speech can resurrect either the entire concept or parts of the concept. This has been achieved through the extended and shared construction, and multifarious use or the gestured depiction that slips and slides across the functions for communicating a concept, thinking through information, and directing the interaction.

Conclusion: What has been gained from the analysis? In summation, Episode 4 adds to the categories of phenomena that emerged in Study 1 and are further supported here in Study 2. That is, that gestured depictions evolve over time and collaboratively across participants, gaining more value across use. By Episode 4, the interaction has earned a critical shared agent in the “interwoven hands” depiction. This shared agent becomes the mediator that allows the teaching and learning to extend further. Once the gestured depiction is accepted as a shared association, the gestured depiction can be mobilized to activate further achievements that extend knowledge as it becomes a collaborative resource for learners and a tool to ground information. This is bringing Raya and Ellie closer into the discipline. In the process of disciplining perception, the “interwoven hands” depiction becomes a vehicle that invites the learners into the discipline, even if only to the very periphery of it.

Discussion and Implications: The Gestured Depiction As Participant in Interactive Explanations

In Study 2, I set out to show that categories of phenomena uncovered in the prior analysis (Study 1) of brief segments, lasting less than a minute are also present in a single

extended explanation lasting over 40 minutes. Study 2 reveals that the use of gestured depictions can persist and develop throughout an entire explanation, becoming a seminal resource for communicating and building meaning in interaction. This is an important finding because it shows the hands and body are not just single and brief resources used intermittently in explanations. They are more prominent than that. Gestured depictions serve as coherent, critical, and sustainable resources used strategically and systematically to build the teaching and learning of a layered and complex concept over time and across the development of understanding.

Study 2 further illustrates that explainers have practices for bringing a depiction into existence for the recipients in order to represent ideas. This includes not only the presentation of the salient depiction but the set-up of it as well. The set-up includes organizing participants to orient to the action to come. Once this is achieved, the building of the gestured depiction is a sequentially scaffolded step-by step construction in which the maker highlights relevant aspects of the gestured depiction and guides the recipients' perception to the gestured depiction. Recipients also participate in this construction process through bodily demonstrations of their attentional orientation and the level of alignment to the explanation. As a result, the building process is a moment-by-moment, improvisational process shaped by all participants.

Study 2 further supports that gestured depictions are complex and flexible tools. They can slide across functions for communicating information (the maker's gestures are "for you"), thinking through information (the maker's gesture are "for me"), and steering the interaction toward the shared goal (gestures that are "for us"). The flexibility, as well

as the opportunity, for gestures to cross and mix functions lends to their potential richness to participate in the process of teaching and learning.

There are also depths of layers in which how participants can engage the depiction. They can exist between acting as a visual resource in which the hands as a concept are observed, or a visceral experience in which the hands as a concept is felt in the body. The analysis suggests that learners in the process of gaining new information move across these perceptual experiences.

In conclusion, the shared, moment-to-moment construction of a concept across experts and non-expert becomes an overlapping of experiences with the gestured depiction and uses of the gestured depiction across and with participants. This analysis further supports gestured depictions as a functionally flexible medium in which understanding is shared, worked out, and constructed. It further clarifies how the artful production, strategic employment, and the perceptive recognition of gesture is a critical interactional activity for teaching and learning that is achieved and negotiated by all participants.

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CHAPTER 7

STUDY 3: REMADE BY HANDS - THE LEARNERS' GESTURAL RE-BUILDING OF LEARNED CONCEPTS FOR RE-EXPLANATION

A careful collection of instances of gestural usage and the analysis of how they contribute to the way in which co participants make sense of the interactional move of which they are part of can provide us with a rich understanding of the diverse ways in which gesture is important to participants -Kendon, 1986, p. 6

We cannot rightfully call gesture communicative unless we know something about the things listeners do with them when they see them in a turn in a conversation. – Streeck, 1996. p. 240

Introduction: Redistribution of The functional Role of Gestured Depiction for Learner Re-explanation

Savas, my son, was explaining to me what he discussed in his fourth grade science class. He was telling me about the intricate balance of an eco-system. Savas spoke, “You see, things have to be...”. Here he paused. His hands lifted to the level just below his waist, his palms open and facing upward. In the space within the pause, Savas moved his hands in opposition; as one was up the other was down, like a balancing scale. The gesturing was subtle and brief and performed close to his body. The practices for the gesturing give evidence that gesturing was intended primarily for him and not for me. He continued on and said “in balance”. As he said these words, he lifted his hands higher, pushed them

forward towards me and repeated this gesture with larger motions. This time, the practices for gesturing suggest that the depiction is meant to be for me. I asked him why he did that gesture. His response was, “That’s what Ms. Carlson did when she explained it to me.” Savas’s story suggests that the gestures engaged in the prior explanation with his teacher matter to Savas as he carries them with him across time to his re-explanation to me. His carrying the gestures over time also give hint to what listeners do with gestured used to communicate information. They use them to think through information as well as to share information.

Data and Analysis

The data consists of Raya and Ellie’s individual re-explanation that took place two days after the explanation. I compared gestures used to depict information in the original explanation event to the gestures used to depict information in the re-explanation event. I noted gestural practices in the re-explanation that corresponded, related to, or contradicted gestural practices used in the explanation. I set moments of the use of “interwoven hands” depictions in the expert explanation against the use of same gestured depiction in Raya and Ellie’s re-explanation. I subjected these to sequential analysis to further understand how gestured depictions are used across time.

The Findings

The original purpose of investigating the re-explanations was to answer the question of whether highlighted gestures employed by all participants in the interactive explanations carry over into the learners’ re-explanations. They certainly do, as Savas’s story suggests

and as the data will reveal. The interwoven hand depiction in which the fingers of one hand weave in between the fingers of the other hand to reference the material configuration of a polymer cell first built in the explanation travels with both Raya and Ellie into their re-explanation. This depiction is referred to as the “interwoven hands” depiction. It is created as the fingers on one hand weave in between the finger of the other. In general the “interwoven hands” depiction is related to the construction and mechanism of a polymer cell. In Raya’s 27-minute re-explanation, the “interwoven hands” depiction, and its various adaptations, appears a total of 22 times in Raya’s hands. In Ellie’s re-explanation, the depiction appears 8 times. This evidence, although simple, is meaningful. It shows the Raya and Ellie treat the depiction as a significant part of the explanation and understanding of the concept so much so that it carries over into further talk. The broader implication is that the body is fluidly drafted into service in teaching and learning interactions that extend over time. The bodily depictions are not ephemeral, fly-by-night adornments to explanation, but are rather critical and lasting resources for developing understanding, communicating meaning and executing interactions.

It is certainly important in itself that the gestured depictions used in the interactive explanation re-appear in the re-explanation. But the data reveal more! Participants in the re-explanation, although employing the same gesture in similar form, employed different practices for depiction. This raises a question about how the functional role of the reappearance of the depiction may change when the context changes from an expert’s explanation to a learner’s re-explanation. With this question in mind, I closely examined the gesturing practices and their elements deployed by Raya and Ellie in the re-explanation; comparing them to Bram’s.

In the analysis of the re-explanations I concentrate on the re-use of gestured depictions related to the concept of fabrication of polymer solar cells. I focus particularly on the re-appearance of the “interwoven hands” depiction. I consider its direct re-use, its variations and adaptations as well as auxiliary gestures that partner with this depiction. I frame this analysis by following the specific “interwoven hands” depiction that has come to hold the concept, as a way to provide opportunity for understanding how this previously mutually constructed depiction functions and evolves over time and across events and between participants.

The analysis reveals that in the re-explanations gestures continue to be tactically employed as communicative tools (gestures “for you”), thinking tools (gestures “for me”), and tools to direct interaction (gestures “for us”). One important difference between the gesture use in the explanation and the re-explanation is the distribution of these functions. For instance, while the expert-as-explainer uses the depiction dominantly as a resource to express information to his recipients, the learner-as-explainer makes more extensive use of the depiction as a tool to think through ideas in the process of organizing new information for communication. And this is not surprising. The learner, now as explainer, has inherited different interests in the re-explanation than the expert held in the explanation. She is challenged with not just conveying a newly learned concept, but recalling and piecing together of newly learned ideas into a sufficient explanation for a listener. As a result, explaining and learning collapse into one event, at times more successfully than others.

Earlier I introduced the term “interactive explanations” to express that the explanation of concepts can be a dynamic exchange between people, the context, and the

resources available and activated in a learning arrangement. In an expert's explanation, I have showed that the interactivity influences the planning, the execution, and the reception of the explanation, allowing for the unfolding of a progressive exchange that leads to the achievement of conveying a concept to the non-expert. In "interactive re-explanations" the goals for the learner-as-explainer become more complex than conveying information successfully. The learner-as-explainer is not yet an expert. She is in a position of transitioning knowledge. She is charged with both the challenges of coming to a level of understanding AND achieving an explanation of a newly learned concept to a less knowledgeable other. In response to the changing goals, the interactive structure of the re-explanation becomes something different from the original explanation. The data reveal that the gestured depiction becomes part of the new structure. But its role is different in the re-explanation. It now becomes a very active agent for the learner-as-explainer to support thinking to bring new knowledge to a level of sufficient articulation for the less knowledgeable recipient. One function gestured depiction serve is to connect the past and present conversations. The gestured depiction becomes a bridge to carry information over time. When enacted as a thinking tool it also becomes a manipulative to think through information in the presence of the less knowledgeable other. In the successful interaction of working through ideas in front of the recipient of the anticipated explanation in construction, the gestured depiction assumes a muddled, mixed, and changing role that works "for me" as a thinking tool, "for you" as a source to communicate information, and "for us" to shape and direct the interaction toward the newly acquired goals present in the learner's re-explanations.

Treating gestured depictions as transporters and connectors. In the re-explanation, as a learner-as-explainer uses the gestured depictions for thinking, I take time to expand a frame to analyze gestures as depictions for thinking in re-explanations to better decipher how they are working for the learner as explainer. In support of thinking the re-use of the gestured depiction can work to help recall information and to order that information to achieve a cohesive understanding that can, in turn be used to communicate to the present participant. Both Raya and Ellie use gestured depictions created in the explanation to think through the concept in the absence of the expert and in the presence of a less knowledgeable recipient in the re-explanation. With one of the learner-as-explainers' interests is to recall information and make sense of it without the expert present, the gestured depiction becomes a vehicle for transferring and organizing understanding. Compared to an expert's explanation, for the learner in the process of a successful re-explanation, the gestured depiction spends much of its time as a depiction for thinking. In support of the activity of thinking the, gesture acts as (1) a transporter, and (2) a connector. As a transporter it helps the learners recall bits and pieces from the past conversation and bring them into the present one. It becomes an intermediary (Latour, 2005) that carries aspects of the concept over time from the expert explanation to the re-explanation. In the service of thinking it also acts as a connector. As a connector, the gestured depiction allows for the assemblage of pieces into a comprehensive whole.. In the process of assembling, the concept finds form. As the gestured depictions are assembled into a string of ideas, the ideas then can be mobilized to achieve a change in understanding. At this point in the evolution, the gestured depiction becomes a mediator (Latour, 2005) as it works with talk to assemble parts in a cohesive whole that then

initiates thinking toward a construction that can eventually mobilize information to support the translation of discreet parts into a comprehensive and cohesive understanding of the concept

This study is divided into 2 cases. Case 1 is an analysis of Raya's re-explanation. Raya successfully engages the affordance of the gestured depiction as a thinking tool to achieve explanation as she integrates and balances transporting information, assembling information and communicating information. Case 2 is an analysis of Ellie's re-explanation. Although both Raya and Ellie participated in the same explanation event, experiencing the same gestured depictions, Ellie's is unable to successfully balance the gestured depictions for thinking and communicating to achieve re-explanation.

As a result Ellie's re-explanation not being nearly as successful as Raya's, I am encouraged to investigate why this is so. For Raya and Ellie, the same gestures are present and used in the explanation but demonstration and development of knowledge is different in the re-explanation. It makes me wonder if there is a relationship to how the learner experiences and engages gestured depictions in the explanation to its functional value in the re-explanation.

This becomes an important inquiry for teaching and learning in explanation because it may point to the importance of creating specific experiences with the gestured depiction to enhance understanding and continued learning with the gestured depiction across time.

Case 1: Raya's Rebuilding of the Gestured Depiction for Re-explanation Gains her Understanding

In Case 1, I show how Raya's varied uses of the gestured depiction in her re-explanation act as resources to support her on-going learning in the process of re-explanation. The case makes a point that gestured depictions used in explanation not only travel across time with the learner, but also serve the on-going development of understanding in the absence of the expert. This is important because learning can be measured by what the learner can increasingly do on her own, without the support of the expert.

Raya meets with Lia in the student lounge of the College of Education building two days after her explanation conversation with Bram. Her 27-minute re-explanation is shared with Lia; a confederate acting as recipient. Lia was instructed to learn the concept well enough to be able to explain it to another. Raya was instructed not to review any of the material and was told that we were only interested in what she learned with Bram.

I examine four segments from Raya's re-explanation event and illuminate examples that show how the gestured depiction established in the prior explanation is pressed into service to support continued learning in the process of re-explanation. I introduce four emerging themes. First, the gestured depiction does, in fact, re-appear in the re-explanation. Second, the gestured depiction carried over to a learner's re-explanation works as a depiction to support thinking. As so, in the process of rebuilding the concept in talk and action, the learner uses the gestured depiction to transport AND assemble knowledge. Finally, the less knowledgeable recipient supports the learner-as-explainer's construction of the concept. Together, this process develops toward a re-explanation in which the gestured depiction moves away from being a depiction for thinking but a depiction to communicate newly developed understanding. Together the

themes suggest how the gestured depictions in interaction for re-explanation are a central resource for learning across time and events.

The gestured depiction first reappears in re-explanation as a thinking tool.

This first segment illustrates the first re-appearance of the gesture depiction in the re-explanation primarily used as a resource for Raya to recall the concept. Her use of the gestured depiction shows Raya accepts the depiction as part of the concept so much so that she carries it with her over time.

“Of this material”

1.	RAYA: They're trying to find a correct chemical configuration
2.	of this material (.)
3.	LIA: OK
4.	Uhm... in order to make.
5.	In order to make it
6.	possible for electricity to happen (.)
7.	So for a current to happen.
8.	Uhm...

Figure 7.1. Transcript of talk

As Raya says, “They are trying to find a correct chemical configuration” she lifts her hands off her lap. By the time she concludes the sentence with “this material” the depiction is loosely constructed. It exists in the horizontal plane (as opposed to its more common vertical positioning in Bram’s hands). It remains close to her body and on the lower quadrant of the interactional stage (see Figure 7.2). Her gaze remains on Lia, never directed at her own hands. Lia gazes briefly at Raya’s hands, and, nods and then says “OK”. After Lia nods, Raya’s gaze drifts off into the global space to her right as she says, “Uhm”. She maintains the depiction as she utters a soft-spoken “in order to make” with her gaze off to her right (see Figure 7.2).




		
2: RAYA: <u>of this material</u> (.)	3: LIA: OK	4: RAYA: Uhm...in order to make
<i>Raya creates depiction. Gaze remains on Lia. Lia nods and briefly gazes to Raya's hands</i>	<i>Raya maintains depiction as Lia talks.</i>	<i>Raya still maintains depiction as she resumes her talk.</i>

Figure 7.2. The first appearance of depiction helps Raya recall the concept

Raya continues. In her repeat of the talk, “in order to make,” her hands pull out of the “interwoven hands” depiction and perform two beat gestures. (One beat as she says “In order”. The other beat as she says “to make”). As she performs the beat gestures, her gaze returns to Lia. As she continues and utters “so for a current to happen”, Raya uses the index finger of her right hand to trace out a circle in space (see Figure 7.3). Her gaze remains toward Lia.



	
5. RAYA: . <u>In order to make</u> it 6. Possible for electricity to happen (.)	7. RAYA: So for a <u>current to happen</u>
<i>Raya's hands perform two beat gestures. One as she says “In order”, the other as she says “to make”.</i>	<i>Index fingers trace out a circle in space</i>

Figure 7.3. The first appearance of depiction helps Raya recall the concept of current

In the segment just shared, the mere appearance of the “interwoven hands” depiction reveals that Raya regards the hands as holding salient information from the

passed conversation that she needs for the present one. This is significant in itself. But what is of more interest than the re-appearance of the gestured depiction is its changed functional role for the maker. It is first and foremost a depiction for Raya's thinking. It is created for her. This is different from Bram's first presentation of the depiction in the explanation. Her elements of her practices for depiction are clearly different than Bram's. Raya creates the depiction in her near space, not intentionally highlighting it for her recipient. Bram explicitly pushes forward a solidly constructed depiction into the interactional space and in the sightline of his recipients. It is created for their benefit. The elements of Raya's practices for depicting of being brief, loose, and predominantly close to her body suggest a different intention than Bram's. The gestured depiction is made for her benefit, not her recipient's. It is working as a reflective knowledge-building tool for her that is transporting the general gist of the basic concept of how polymer cells work from the past conversations to the present.

Although serving as a depiction for Raya, by the mere fact that the depiction is public, the gesturing ends up serving the interaction as well. As present in the interaction, although not intentionally highlighted, it functions as a tool to set up an interface between the two participants simply because Lia takes note of it. As Raya maintains a direct gaze on Lia (see Figure 7.3) as she creates the depiction Lia's gaze briefly shifts to Raya's hands (this brief shift cannot be captured in a frame grab because of the limitations of the tool). Lia responds with a nod and an audible "OK". Lia's brief glance to Raya's hands suggests that Lia deems the hands as a possible element in the interaction.

In this first appearance Raya is already balancing thinking through ideas with attending to keeping her recipient in the interaction – a demanding challenge for the

learner now as explainer. Her introspective “Uhm”, with gaze off to the distant right, to a switch to an assertive and direct talk partnered with the movement of the hands as an instrument to perform attention-calling beats to the words “in order to make”, represent a movement from ‘for me’ to ‘for you’ that works to shape the structure of the interaction that sets up the expectation of how the interaction is going to play out. The moment-to-moment switches in practices between being “for me” and ‘for you’ demonstrate Raya’s attention to the challenge. Raya begins to establish that her position in this re-explanation is both as learner and explainer. She has established that she will be moving between thinking and communicating. Lia’s involvement has also been established with her head nod and a confirming “OK”. Although not directed to look to Raya’s hands through Raya’s practices for depiction, as Lia watches Raya think through information, Lia is able to assess that Raya is balancing the challenges of thinking through new ideas and communicating new ideas. For now, Lia assumes the position as attentive and patient recipient, while Raya re-constructs the concept.

If we consider Raya’s positioning as being somewhere between a new learner engaging in a process of self-explanation and a conversant explaining to another, her shift across practices and element of practices makes sense. The depiction is taking on multiple functions, none of which are fully fueled. It is simultaneously acting as a tool to transport knowledge as well as an intercessor to keep her recipient involved enough to buy her time to think through ideas. She is tiptoeing somewhere in that hybrid space between depicting for thinking and depicting for communicating, balancing her interest as a learner organizing new information with explainer charged with expressing information to a less knowledgeable other.

With this first appearance of the “interwoven hand” depiction, Raya’s very skeletal explanation of the concept expresses a basic recall that the configuration of molecular material has something to do with soliciting electron transfer. The skeletal structure is depicted in the talk and gestures.

The skeletal structure maintains a simple but correct narrative of the mechanistic process. It is present not only in her words but also her actions. It starts with “material” as she models the material with the “interwoven hands” depiction. Raya shows her understanding that what takes place next is “for a current to happen”. She does this as she traces out a circular pathway. The two gestures together show that Raya has an awareness, although not yet complete, that the concept is a progressive relationship that begins with a certain “material” and concludes with a “current”.

This first attempt at re-explanation does not, however, express an understanding of *how* this happens. Important information between the beginning and the end is not yet recovered nor assembled. This develops in the next attempt through the use of the hands as the rebuilding continues.

Gestured depictions carried over to a learner’s re-explanation generate information. The depiction used to explain a concept in an explanation event needs to be more than just transported to the re-explanation to affect a change in learning. It needs to be mobilized as a resource that can support the rebuilding of the concepts. In the following segment I show how gestured depictions carried over to Raya’s re- explanation expand her understanding of the concept in the process of her re-enactment of them. The re-enactment of the gestured depiction allows her to generate information through her own hands through a process of “seeing” information in her hands and physically

experiencing information through her body. Through these perceptual experiences she is able to use the gestured depiction to transport bit and pieces of the concept and to then assemble loose parts into composites of new knowledge. This generation of new information contributes to an assemblage that can then be put into further action to mobilize new understandings.

“He did this thing”

- | | |
|----|---|
| 1. | RAYA: So they are trying to find (.) umm material - |
| 2. | God he did this thing where its- |
| 3. | They're trying to find (.) material |
| 4. | that will attract the electron, |
| 5. | that has that low potential energy. |
| 6. | And it does some thing where it pul- |
| 7. | so it pulls the electron and then |

Figure 7.4 Transcript of talk

Example 1. “Seeing” the depiction to pull out information. In the following segment I show how Raya engages the gestured depiction as a thinking tool to “see” information in her hands. Although enacted in her own body, Raya augments her experience with the gestured depictions as graphical resources by visually examining her hands as external models.

As Raya’s hands are suspended in the air she says, “So they are trying to find, uhm, material -” (see Figure 7.5). Raya’s utterance of the word “material” is followed by a lull in talk. In this moment, Raya begins to carefully slide the fingers of one hand in between the fingers of the other (see Figure 7.5). Her gaze is to her moving hands. The movement of one hand into another is deliberate, slow, and closely observed in the absence of talk. As she says, “God, he did this thing where its”, she lifts her hands directly into her sightline. Gaze goes to her hands that are vertically positioned (like Bram’s first presentation). She holds the depiction in space. In an absence of talk her gaze is maintained directly on the depiction (see Figure 7.5).




		
1. RAYA: So they are trying to find (.) uhm (.) material -	(no talk)	2. God he did this thing where its-
<i>Performs beat with hands as she utters “material”</i>	<i>Raya slides fingers in between one another. He gaze is to hands.</i>	<i>Completes 2nd appearance of depiction and gazes to own hands.</i>

Figure 7.5. Raya engages depiction as a visual resource to gain information

Raya’s practice of looking to her hands suggests that she is giving preference to the visual affordances of her hands as a depiction to be observed. Her visual scrutiny of the hands shows the depiction as a physical external model holds information that is visually accessed while being viscerally experienced. It is the “thing”. But at the same time it is also an action, recalling what “he did”. She accesses the thing and its action to call up information. By looking at the actions in her hands, Raya gains two perceptual experiences while performing the gesture. It is felt and seen. It is both viewed and experienced. The two perceptual experiences broaden her interaction with the depiction.

Example 2: Generating information through a series of actions and talk. In segment 2, I highlight another way the gestured depiction works as a depiction for thinking. When Raya enacts the gestured depictions, the gestures can act as bits and pieces of information that dynamically generate and bring forth new information through the process of constructing them. I show that transportation of pieces of the concepts through gestural enactment is a process of accumulation where the employment of one gesture can trigger another piece of information held in talk and in the body.

In this next example, Raya remakes the depiction from the prior example but sequentially adds on pieces of information to generate information about the “thing” she holds in her hands. Performing the practices and elements that define gestures as depictions for thinking, Raya remakes the depiction close to her body when she begins talk (They are trying to find). Her gaze goes to her hands after the pause and right before she utters “the material”, calling up the aspect of concept that there is a certain “material” in both her talk as she says the word, and her in body as she makes the model (see Figure 7.6). She adds on.



3. RAYA: They are trying to find (.) material

Raya creates the depiction and names it as “material” Gaze drop to her hands before she creates the depiction

Figure 7.6. Raya uses depiction as thinking tool to recall aspects of “material”

Her next gestural move is the reenactment of the “pull gesture” she previously created and performed in the original explanation event. Her right hand reaches out into the shared space in front of her, and with swiftness and directness, she closes her hands around the space and pulls her arm inward toward her body as she says, “That will attract the electron.” (see Figure 7.7).



4. RAYA: That will attract the electron

Raya performs own gesture to experience attraction. Pulling hands inward as she utters “attract”.

Figure 7.7. Raya performs own gesture to enact “attraction”

What the partnering of these two gestures has gained her is a recall of information that the material is an agent for attracting an electron. She continues to add on. She immediately moves on and shakes her right hand to reference it as material that has a “low potential energy” (see Figure 7.8) After achieving this understanding, her gaze connects with Lia for a brief moment before she moves back to gesturing “for me”. Once again Raya demonstrates how she is balancing thinking through on her own with also having to explain to another.



5: That has that low potential energy

Raya's gaze goes to Lia as she enacts "low potential energy"

Figure 7.8. Raya uses gaze to connect with Lia

In the next moment she enacts an abbreviated and smaller version of the pull gesture, as she says, “and it does something where it pu –“. Immediately following she re-enacts the pull gesture a third time. This time it is larger. Her talk accompanying the gesture in as she says, “So it pulls the electron”, is a conclusive wrap up of the information she has earned through the enactment (see Figure 7.9)

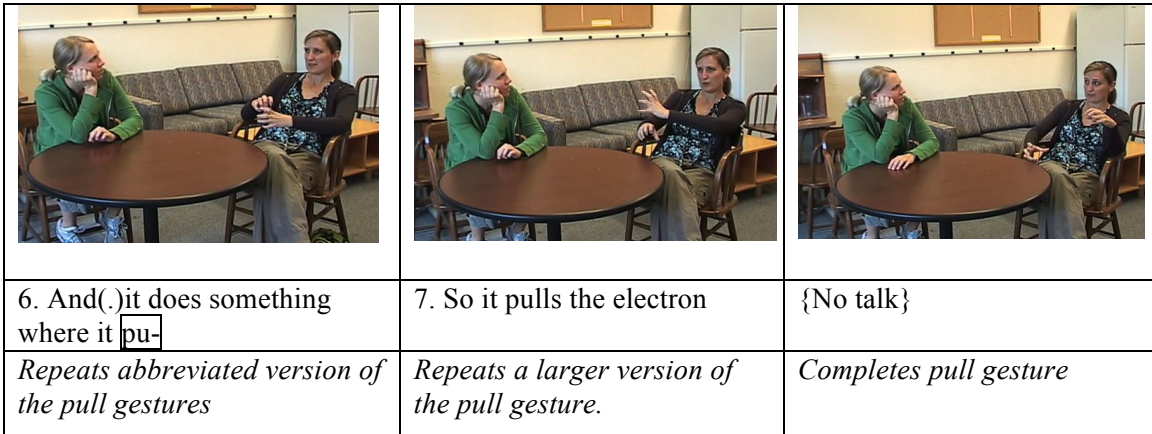


Figure 7.9. Raya uses a series of gestures to assemble information

In summary, Raya, through coordination and repetitions of different variations of the original gestured depiction, has transported some, but not all, critical aspects

associated with the concept. Pieces of understanding have accumulated. She now knows (1) there is a material, (2) the material needs to attract an electron, (3) the material has a low potential energy and, (4) the material captures the electron through a process of pulling inward. Example 1 and 2 together demonstrate that the transporting and generating of information over time happens between an interaction of gestures and talk. Each modality of talk and action support the transitioning of bits and pieces of information toward a composite construction of the concept. Breaking down the action into perceptual experiences of gestured depictions as something both seen and felt, viewed and experienced, there is also an accumulated integration between the gestured depiction as being experienced as a “thing” to visually examine and the gesture depiction being experienced as an action used to viscerally perceive. The interaction of perceptual experiences also contributes to Raya coming closer to a better understanding of the concept.

Example 3: Assembling bits and pieces of information to achieve understanding. It is not enough to transport pieces of the concept if understanding is to be extended. Raya also needs to assemble the bits and pieces into a whole. At this point Raya has transported the essential pieces of the concept. Her work now is to craft them in an order. Imagine building an object out of Legos. It becomes similar to the act of my son re-building the Lego Space Shuttle he built with his expert-Lego-builder friend. This time he does not have the manual or his expert friend with him. He only has the loose pieces of the full construction mixed in the box. He begins to piece together one piece by one piece, taking them apart and reconfiguring them, until he has a chunk of one of the parts that make up the Space Shuttle. Now he needs to put these chunks made up of bits

and pieces together to get to the whole. This is much like Raya’s rebuilding of the concept in the next example. Example 3 shows how Raya begins to assemble the collected and constructed parts into an understanding of the concept.

“How did he describe this?”

- | | |
|-----------|---|
| 1. RAYA: | Oh god. How did he describe this? Sorry. |
| 2. | One part of the material (.) will have that negative (.) |
| 3. | or that low potential energy |
| 4. | and will then seek (.) |
| 5. | the electron and then- |
| 6. | He talked about how, |
| 7. | so then potentially |
| 8. | they're gon-, rather than it would be kind of being sticking up off of the shh- |
| 9. LIA: | Panel? |
| 10. RAYA: | The panel, right. |

Figure 7.10. Transcript of talk

Raya expresses her lack of full understanding in her talk (‘Somehow then those two separate... I don’t really understand’). She drops her head, places her hands on her temples and utters, . The talk that takes her back in time (”How did he describe this?”) is not accompanied by gestures depicting the concept. Instead she drops her head to her hands (see Figure 7.11).



(no talk)

Raya drops her head and pauses in talk after she says “God. How did he describe this?”

Figure 7.11. Gestured depiction transports information

Raya’s action and pause in talk can suggest that she is momentarily accessing a mental space – a place inside the head where knowledge can live. If so, this is short lived. She immediately takes up a series of gestured depictions, enacting one after the other. Here again is another example of how recalling information and making sense of it is an integration of experiences. The data suggest that the mental space alone cannot get her the information. She also needs the hands. Not alone

Raya proceeds to rebuild half the “interwoven hands” depiction to represent the “one part of the material” Her gaze is to her hands (see Figure 7.12). The physically enacted depiction is also being apprehended visually.



2. One part of the material (.)

Stabilizes left hand on surface of her leg

7.12. Gestured depiction helps to gain information

From here on her talk speeds up. Her fast-paced statements are incomplete and self-interrupted. Her gestural production is rapid as well. Raya is assembling parts that she has transported. She links up the presence of energy as she shakes her left hand and says “negative” and “low potential energy” (see Figure 7.13).



Figure 7.13. Raya shakes hands to reference “energy”

By enacting this gesture and partnering it with talk, she adds details for both her and Lia about the kind of energy this “one part of the material” retains. But for both participants the action serves a slightly different purpose at the same time. The shake for Lia it is employed by Raya to communicate where the energy is in the material. The shake for Raya, although intended to communicate, also serves to ground the information for her.

In this process of depicting that is a balance between depicting for thinking and depicting for communicating, Raya, then moves to place one hand upon the other, connecting the aspect of the concept that one part of the material, the part she made with her hands just seconds before, is seeking an electron (see Figure 7.14).



5. will then seek the (.) the electron and then-

*Raya places left hand upon right as she says "seek".
Maintains gesture through out talk.*

Figure 7.14. Gestures help accumulate information

The swift connecting of bits and pieces of the full concept continues. Raya slips the fingers of her right hand into the space between the fingers of her left, recalling the talk and gesture Bram performed to represent the necessary relationship between the two material needed to create a current. She brushes her hand across the plane of the table, tracing out the surface (see Figure 7.15). (A gesture previously performed by Bram to indicate layers of the material of polymer solar cells). After this swift gathering of gestures, she sits up tall, presses her body forward in space and returns to the half the “interwoven hands” depiction that started this stream of assembly that represents “one part of the material”.




		
6. He talked about how, so then (.)	7. So the potentially they're gonna (.) rather (.) that	8. that, then it would be kind of being sticking up off of, shh
<i>Raya slips index finger of right hand into the space between the fingers of the left, recalling the relationship between the two materials needed to create a current.</i>	<i>Raya slides her hand across surface of table, a gesture previously performed by Bram to indicated layers of the material of polymer solar cells.</i>	<i>Raya recreates "one part of the material" gesture performed earlier. Begins construction with "that". Holds it through out talk.</i>

Figure 7.15. Gesture depiction helps assemble parts of the concept

The quick depictions are settled between “assembly talk” that indicates a coming to a realization through a process of a series of enactments. Gestures appear between such talk as “will have” “then”, “so then”, “that” “rather”. Together the talk and gestures add up to create a string of sewn together information. She follows this swift stream of interacting talk and action with change in posture and a change in her manner of talk. She sits forward and recreates the gestured depiction representing “one part of the material”. Her talk is louder and the words are uttered with clarity as she presses forward in her seat, “that then it would be kind of sticking up off the (.) shhh –“ (see Figure 7.15).

In this stream of talk and action Raya demonstrate how she interactionally balances the challenge of needing to simultaneously think through new information with the gestured depiction and communicate new information with the gestured depictions. Through out the talk and action, Raya has moved from a consequentially public display of gestured depictions to support her thinking to gestured depictions explicitly used to communicate the information she figured out in her process of thinking through with the

gestures and talk. In her process of “thinking through” it is important to note how the talk and gestures inter-modally play off one another in order to assemble together parts to achieve a more comprehensive whole. This rapid action for transporting and assembling, rolls her toward a change in her level of understanding as demonstrated by the accumulation of details. The enactments in her hands and her talk together lead her to an understanding. This development of understanding also allows her to move closer to assuming the role of explainer, sharing newfound knowledge with Lia.

Once she has achieved a level of construction cohesive enough to intentionally communicate to Lia, she performs a postural switch and presses her body into the interactional space. Her gestured depictions for thinking, made available to her recipient to observe, become depictions for communicating information to Lia

Recipient supports the construction of the re-explanation. The direct presentation of a gestured depiction to communicate information to Lia changes the interactional relationship between Lia and Raya. Up until now, as established in the first presentation of the depiction, Lia has assumed the patient role of learner waiting on the sidelines while Raya thinks through information. But from here on out, Lia’s role changes. Lia becomes an active participant in Raya’s reconstruction of the concept. It is not only the talk and gestures that support Raya’s thinking, now Lia does so as well.

The following examples represent how learning in the process of interaction can be an achievement between participants where the less knowledgeable recipient becomes a kind of memory resources for the learner-as-explainer trying to learn in the process of re-articulation.

Example 1. Gestures mediate collaboration for word search. In the example to follow, Raya's gestures mediate a collaborative process in which Lia supports Raya's construction of the concept by provides missing information.

<p>RAYA: 7. So the potentially they're gonna(.) rather (.) that 8. that, then it would be kind of being sticking up off of (.) a shh (.) LIA: 9. Panel" RAYA: 10. The panel. Right</p>

Figure 7.16. Transcript of talk

Raya sweeps her hand across the table. Her talk pauses as she says "sticking up off of". Raya pauses, unable to pull up the word to describe her depiction. Responding to Raya's previous gesture, Lia offers the word "panel" (see Figure 7.17) to help complete the talk.




		
7. So the potentially they're gonna(.) rather (.) that	8. that, then it would be kind of being sticking up off of (.) a shh (.)	9. LIA: Panel? 10. RAYA: The panel. Right.
<i>Raya slides her hand across surface of table., a gesture previously performed by Bram in the explanation and by Raya in the re-explanation to indicate layers of the material of polymer solar cells</i>	<i>Raya recreates "one part of the material" gesture performed in unit 17.</i>	<i>Lia gazes to Raya's hands and offer the word panel. Her hands begin to move together with fingers spread as she speaks. Raya maintains depiction while her gaze moves to Lia.</i>

Figure 7.17. Raya depicts "panel"; Ellie provides word in later context

Lia's capacity to offer the correct word in response to Raya's gesture requires some assembly of her own. The word "panel" is likely achieved through a composite of talk and gestures accumulated across recent units. There is not enough information in the gesture alone for Lia to get that Raya is invoking a "panel". But there is enough

information from previous talk. Raya has already discussed that there are “panels” on which layers of material are spread. Lia matches up the current gesture with passed talk to construct the idea of panel from the gesture. Like Raya, Lia is also connecting and assembling parts from talk and gesture over time. Her achievement is a result of sewing together already transported and accessible loose parts.

Lia’s input to support Raya’s word search does more than support Raya’s thinking. It indicates that Lia is an active participant in the interaction. It confirms to Raya that Lia, although relatively silent, has been attentive to both her talk and her gestures, validating Raya’s ability to think through the concept while maintaining the attention of her recipient, and further encouraging the use of gestures as a central part of the re-explanation.

Example 2: Gesture mediate collaboration for concept confirmation

Lia’s support proliferates as the conversation moves forward, further defining her changing role from passive, yet attentive, listener to supportive and contributing listener. Both participants are now involved in the in a back and forth construction of the concept together.

“Charge”

- | |
|--|
| 1. RAYA: and then what’s left is the positive energy |
| 2. because the electron’s a [negative, negative] |
| 3. LIA: [Right. Charge] |
| 4. RAYA: charge. |

Figure 7. 18. Transcript of talk

After several demonstrations of shaking hands representing energy, this time when Raya holds up her hand and shakes it in the absence of the word, Lia steps in and offers the word “charge”. Raya, in turn, confirms “charge” is the word she is looking for.

She confirms this in talk and gestures as she says “right” and as she shakes her hand again (see Figure 7.19).



	
<p>1. RAYA: and then what's left is <u>the positive energy</u></p>	<p>2. because the electron's a [negative, negative] 3. LIA: [Right. Charge] 4. RAYA: charge.</p>
<p><i>Raya shakes her hands. Gaze is to Lia.</i></p>	<p><i>Lia offers the word “charge” and Raya confirms it is the word she is looking for with both talk and gesture as she shakes her hand again</i></p>

Figure. 7.19. Lia provides missing word as Raya depicts the “word” in her hands.

This exchange supports the development of the concept for communication. The action also performs an interactional role as it further confirms the structure of the discourse as one where gestures and talk intermingle. This awareness of the element of the interaction is evidence by that it is not just the present gesture that gives Lia the information and allows her to fill in the talk. Her knowledge comes from the three previous times Raya shakes a hand and identifies it as having “energy” or “charge” inside the material. As the interaction rolls forward, Raya and Lia are building shared associations that support the achievement of joint understanding.

Example 3. Gestures mediate concept building together. I have shown that gestures and talk are initiated based on emerging needs of the participants in the interaction. Lia recognizes Raya’s need for support as she offers missing words. Lia’s

Lia steps in and offers her information by reminding Raya what she had shared before. As Raya holds the depiction, Lia points to it and then re-creates a brief, loose version of it in her own hands as she communicates, “Before you were saying it would be something (.). That needs something different in order-“ (see Figure 7.22).



	
<p>3. LIA: Before you were saying it would be something (.)</p>	<p>4. That needs something different in order [to allow a charge]</p> <p>5. RAYA [Right]</p>
<p><i>Linda points to Raya’s gestured depiction</i></p>	<p><i>Lia loosely and briefly creates the “interwoven hands” depiction</i></p>

Figure 7.22. Both participants use gestured depiction

Lia’s take up of the gestured depiction shows that it has become a central resource in the interaction for both participants. The depiction partnered with talk further shows that Raya’s building to think through has also achieved the role of communicating the concept to Lia in both talk and gesture.

Example 4. Recipient takes up gestured depiction to gain clarification. In the next example I show how the gestured depiction, first born in Bram’s hands, is now used by the recipient of the re-explanation to gain confirmation. As Lia says, “That was actually turning solar energy into electrical energy”, she moves her hands toward one another. As she says, “That’s what that-“ she slips her fingers in between one another repeatedly. Raya slides under her talk, creates the same depiction in her hands and says, “That’s what this is”. Both Raya and Lia hold a version of the “interwoven hands”

depiction in their own hands as they gaze toward one another (see Figure 7.23). It is now a shared association for materials in polymer cells that began in Bram's hands, was passed to Raya's hands, and now exists in Lia's hands.



	
<p>6. LIA: That's what [that] 7. RAYA: [That's]</p>	<p>what this is.</p>
<p><i>Lia takes up the "interwoven hands" depiction to gain clarification</i></p>	<p><i>Both Lia and Raya hold the same depiction as a representation of the material configuration of polymer solar cells</i></p>

Figure 7.23. Gestured depiction assumes status as shared association

What is also achieved in this moment is Raya's switch in positioning from learner gathering information to explainer conveying information. In confirming Lia's thinking, Raya has earned the role of explainer. Raya now holds the depiction in her hand as something strictly for Lia. This is the first Raya performs the gestured depiction strictly as a tool for communication. It is for Lia and not for Raya.

These examples show that Raya's progression to understanding also involves the support of her recipient. Firstly, Lia acts as a memory holder for Raya, providing her with information she has lost hold of. Secondly, Raya, by invoking the depiction as a communicative tool for Lia has demonstrated her shift from learner to explainer. I suggest that Lia's take up of the gestured depiction served to alter the interactional arrangement. It did so in that it worked to affirm for Raya that her own understanding has developed. Lia's support allows Raya to organize and assess the information she carries

over and assemble, setting the stage for her to use the now re-constructed depictions to mobilize her thinking to a new level of understanding that surpasses her comprehensive achieved in the explanation event. It has given Raya the go ahead to now move away from the position of learner preparing for explanation and toward the position of one having achieved a level of understanding that can now be articulated with continuity.

Gestured depictions are linked together to create an animated narration of the concept. By the end of the re-explanation event, Raya's practices for gesture and talk carry her over from learner building knowledge in the presence of her recipient and closer toward an explainer conveying knowledge. Here I show that through the process of the coordination the activities of transport and assembly, through the interaction of talk and gestures, through the exchange between thinking through ideas and articulating ideas, Raya reaches a point to where the bit and pieces of information have taken form and been employed to mobilize a deeper understanding. Her newly constructed understanding is share as an animated narration of the concept with her recipient.

“And that would cause the electron current”

- | | |
|-----|---|
| 1. | RAYA: And then this, (.) |
| 2. | then they would make some other material that would (.) |
| 3. | Uhm, I don't understand why, |
| 4. | for some chemical reason, |
| 5. | fill in the spaces that this first material they laid out had made. |
| 6. | And then the light would come through |
| 7. | the sun would come |
| 8. | through this material and |
| 9. | then the electrons would be drawn to this material |
| 10. | and that would cause the [electrical] current |
| 11. | or something like that. |

Figure 7. 24. Transcript of talk

The talk alone as presented in the above transcript reveals a change in Raya's talk over the course of the re-explanation event. The talk now is steady; it lacks pauses. The utterances are also full of “assembly word” - words that are used to string together a

sequence (i.e. “then”, “that”, “would”) in a sequential order for communication. These “assembly” words are accompanied by the “interwoven hands” depiction and the gestures that elaborate upon it. Raya’s understanding has changed.

As Raya begins her to share her now assembles re-explanation of the concept, her left hand forms half the “interwoven hands” depiction when voices “then”. The gesture is referenced in the word “this” and accented with a pulse as she places half the “interwoven hands” depiction on the table. Talk and action are aligned. The talk has the assertiveness and directness of a storyteller embarking on the sharing of a narrative she has told before. As Raya begins to pronounce “then” a second time, the right hand is highlighted with a shake that references it as “some other material”. Both hands come together as she continues talk. Specifically, the fingers of the right hand deliberately slip in between the fingers of the left. She completes the enactment with “that this first material laid out had made.” As she utters “first material” she adds a slight pulse to the left hand (see Figure 7.25). In a slight pause, once the talk in complete, the entire “interwoven hands” depiction is held still, its origins explained.




		
<p>1. RAYA: And then this, (.)</p>	<p>2. then they would <u>make</u> <u>some other material</u> that would (.) 3. Uhm, I don't understand why, 4. for some chemical reason,</p>	<p>5. fill in the spaces that this first material they laid out had made.</p>
<p><i>Raya re-creates “one part of the material” gesture</i></p>	<p><i>Raya lifts right hands and shakes it.</i></p>	<p><i>Raya create the “interwoven hands” depiction</i></p>

Figure 7.25. Raya uses depiction for communicating

In the talk and action represented in Figure 7.25, Raya's talk is clear and directed to Lia. All the gestures that have in prior turns served to activate new information now serve to express information. The gestures are large, fully complete, performed in the interactional space and in Lia's sight line. The communicative talk partnered with the highlighted gestures defines this is an animated demonstration meant for her recipient as an explanation of the concept. Even the talk that declares Raya's lack of understanding ("I don't understand why, for some chemical reason") is a communicative statement directed to Lia conveying what information she cannot provide in full.

Raya continues with the animated explanation. As she moves forward it is not Bram's direct depictions she uses to explain how the light comes through the material. Here Raya provides her own gestured depictions to communicate the concept. Her left hand reaches above her uplifted right elbow and enacts the energy attracted from the sun as she slides the left hand across the pathway created by her arm Her fingers grace the space in between her left hand and then settle for a moment to create a picture of the entire "interwoven hands" depiction as she voices 'through the material'. As she says, "then the electrons would be drawn to this material" the hands return to complete the full "interwoven hands" depiction, expressing the mechanistic cycle in both talk and gestures (see Figure 7.26).




		
6. And then the light would come through 7 the sun would come	8. through this material and	9. then the electrons would be drawn to this material
<i>Raya perform a unique gesture neither performed by Bram nor her to demonstrate the pathway of light through the material</i>	<i>References right hands as “this material”</i>	<i>Pulses lefts hand as fingers of the right slide into finger of the left, recreating the “interwoven Hands” depiction.</i>

Figure 7.26. Raya performs a unique gesture

The creation of her own depiction to explain a part of the concept suggests a change in learning in which the ideas have become absorbed and re-stated as her own. The restatement is demonstrated in the unique gesture she performs. The unique gesture is not a depiction for thinking. It clearly is meant for her recipient. This is evidenced as the gestures are performed in the interactional space. They are large and full and not just in the hands but in the whole body. Her entire body responds to the larger gestures and she leans from side to side, moving with her hands (These full body actions can suggest that the concept has been incorporated into her body). Lia’s gaze is directly on Raya’s hands. Raya’s gaze moves between her hands and Lia’s face, demonstrating joint attentional practices that highlight the hands in order to communicate information to the recipient.

Finally, as Raya states, “and that would cause the current” her hands repeat the circular pathway to enact the idea of electron transfer. (A variation of the same gesture was performed twice before in the re-explanation and was first used by Bram and copied by Raya in the original explanation session). Her hands then come to rest in her lap, her

gaze moves to Lia, and she reclines back in her chair. The re-explanation of the concept is now more fully achieved (see Figure 7.27).



	
<p>10. and that would cause the [electrical] current</p>	<p>11. or something like that.</p>
<p><i>Raya traces a large circle across the horizontal place.</i></p>	<p><i>Raya's hands come to rest. Her explanation is complete.</i></p>

Figure 7.27. The explanation comes to an end and hands come to rest

In this last pass at re-explaining the concept to Lia, thinking processes that were always public and available for the recipient, open up into communicative processes intended explicitly for the recipient. Gestures are performed in the interactional space, in the sight line of her recipient, framed by the positioning of her arms and body. Talk and gestural action are aligned. Gaze moves between Raya's hands and her recipient, a move to maintain mutual attention. Raya's practices have earned her the identity as "explainer in the process of knowledge telling" over "learner in the process of knowledge building". But it is not only the use of particular practices that earn her the identity of explainer; it is also the overall organization of her discourse. Raya's talk and action adhere to a clean sequential structure definitive of explanation, moving from a beginning that presents the idea, to a middle that elaborates and adds specification to the idea, and to an end where talk and hands come to rest and the turn is passed to the recipient.

Case 1: What has been gained from the analysis? Case 1 reveals that gestured depictions not only travel over time with the learner, but also are strategically employed tools to develop Raya's thinking in the process of explaining the newly learned concept to Lia. The gestures function differently with Raya as learner-now-as -explainer than they did with Bram as expert-as-explainer.

The gestured depictions spend more time at the front end of the re-explanation serving to support Raya's thinking than they do to communicate stable information to her recipient, as they did for Bram. But this changes over time. By the end of the re-explanation event, Raya's depiction practices look more like Bram's. That is, the gestured depictions transform into resources to communicate information to Lia as her understanding of the concept develops. As Raya brings the gestured depictions over from the explanation event and employs them as manipulable tools to uncover, assemble, and articulate aspects of the concept they eventually help her construct new knowledge. The data reveal that the change in learning involves the use of the gestured depictions carried over from the explanation to the re-explanation.

If there are criteria, as I suggested in the last chapter, for an expert's successful building of the concept, then Raya demonstrates that there are also criteria for the successful re-use of gestured depictions to build thinking in re-explanation. Criteria for successful re-use of gestured depictions for learning in the process of re-explanation include using the gestured depiction to transport and assemble information, engaging diverse perceptual experiences with the gestured depiction, transforming ideas into adapted and new gestured depictions. Together these actions lead to a mobilization of new understanding.

Raya first uses the gestured depictions to recall and transport information across conversations. The hands remember information out of sync from the original explanation order and only in incomplete parts. But for gestured depictions to be of use to develop conceptual thinking they need to be more than bits and pieces carried over from the explanation. She goes on to use the gestured depictions to assemble pieces that, in turn, mobilize thinking to achieve a comprehensive whole that changes her understanding. She does this in an ordered inter-related partnership with her visceral-visual experiences that links up with talk that also represents aspects of the concept. She strings the talk and gestures together to create a thread of new knowledge. Here it is as if each utterance in talk and each “gestural utterance” (Kendon, 2005) bounce off one another to echo and reverberate meaning that accumulates into understanding. This dynamic process between transporting and assembling aspects of the concept move Raya closer to understanding and thus closer to achieving the role of explainer.

Another criterion for success seem to be a varied and creative use of gestures and ways of experiencing the gestured depiction. Raya uses all sorts of gestured depictions from the explanation. She used gestured depictions she observed Bram perform. She uses gestured depiction she observed Bram perform and that she, herself, performed with him. She also employs gestured depictions she enacted when asking questions to clarify understanding. It is the orchestration of these uses that give the depiction deeper value for transforming understanding.

It also appears that it is not only valuable to engage a wide range of gestured depiction and to give opportunity to diverse perceptual experiences with them. As Raya uses the gestured depictions as tools to transport information across the conversation, she

engages the gestures as depictions as objects to be observed and as actions to be felt, highlighting that gestures provide different levels of perceptual experiences.

Further, Raya develops her own gestured depictions. Raya employs unique gestured depictions. She uses gestured depictions she created in the explanation but, most significantly, she creates her own gestured depiction in the process of re-explanation. The unique gestured depictions she created by the end of her re-explanation are somewhat akin to practices of re-stating an idea in one's own words - a level of understanding we aim to achieve in teaching and learning arrangements) The process of constructing a thought by creatively designing representations that are one's own indicates a level of understanding that goes beyond restatement but rather suggests a conceptual change. As a result the gestures are no longer Bram's, belonging to his explanation. They become hers to demonstrate understanding that now belongs to her. Recall that at the beginning of the re-explanation she lifts her hands and says, "he did this thing". By the final iteration of her explanation, these references to Bram's gestures and talk are gone. Gestures, as well as her thinking, become her own as she adds to them and develops her own gestures out of them.

Finally the opportunity to explore her understanding in the presence of a recipient creates a certain arrangement that Raya balances well. Raya represents a how a learner charged with re-explanation of fresh concept effectively uses gestured depictions by balancing their function for building learning and communicating new understandings. She uses them creatively and strategically in the presence of another. She knows how to use them to support her thinking. She knows how to use them to communicate. She also knows how to use them to make the thinking her own.

Further this overlapping and alternating between the functional uses of the gestured depiction to build her thinking and communicate to her recipient seem to interact in a way to mobilize her learning. One adds to the other. She is able to cycle back and forth between thinking through the ideas and communicating them. As her gestures move from between being “for me” and “for you”, they give opportunity for assessment and revision. Each revision process turns to the hands as the medium to advance her understandings.

In sum the gestured depiction is valuable not in that it is transferred across conversation as a “thing”, a form made by the hands. More specifically, the gestured depiction is valuable because it becomes an active agent that is mobilized in diverse ways to serve multiple goals that deliver Raya to the doorstep of understanding, bringing her closer into the discipline that she was before she started the re-explanation. As the achievement toward disciplined perception is indicated by a new learner moving closer to the talk and practices of the more knowledgeable expert in the field, Raya’s animated explanation shows that she has certainly moved closer to the discipline. This analysis has showed that some of the resources that have allowed her to make this shift include her use of the gestured depiction first performed by the expert, and the interactional exchange that has kept the depiction as a critical resource in building understanding through action.

Case 2: Ellie’s Rebuilding of the Gestured Depiction in Re-Explanation Reveals a Readiness to Expand Learning

If Raya represents a learner-now-as -explainer who successfully engages certain steps and criteria for using gestured depictions previously used in explanation to support a

successful re-explanation AND advance her own understanding in the process of re-articulation, Ellie's re-explanation is an example of when the lack of performance of certain steps and criteria thwarts the potential for continued learning in the process of re-explanation.

Both Raya and Ellie are exposed to the same gestured depictions in the explanation. And Ellie, like Raya, uses these gestured depictions most prominently as thinking tools in her re-explanation. Like Raya, she is challenged with the, sometimes competing, interests of organizing new thinking with communicating ideas to a less knowledgeable other. Unlike Raya, however, Ellie's use of the gestured depictions leads not to a developed understanding of the concept, but rather a realization that she lacks sufficient knowledge to adequately re-explain the concept to another ("I guess I am a little unclear", "I think I got a little confused").

This is an important achievement in a trajectory of learning in itself. It reveals that, although unlike Raya, Ellie has not achieved a significant transition in knowledge. It does show, however, that she is nearly there. This suggests, as it offers an assessment of her learning that Ellie is at a point of transitioning knowledge. The data, then, give opportunity to understanding why the gestured depiction is not as useful to Ellie as it was to Raya. A comparative analysis between the two cases can further give insight to how the gestured depictions can be best employed to further mobilize learning in across explanation and re-explanation events.

In the re-explanation, Ellie employs the "interwoven hands" depiction across a total of eight instances in this 22-minute conversation. This is a significant finding as it supports the assertion that gestures used to explain concepts travel with the learner across

time. The finding also reveals that, like with Raya, the distribution of functional use of the gesture also changes when the depiction is in Ellie's hands as re-explainer compared to its functional use in Bram's hands as explainer. Although still used to communicate information and direct the interaction, the depiction, as it does with Raya, spends more time as a thinking tool.

It is certainly significant that Ellie carries the gestured depictions over time. But why is Ellie's development of understanding in the re-explanation different than Raya's. The result of the analysis is that Ellie's use of the gestured depiction for thinking does not follow the same criteria. For instance, she enrolls the gestured depiction to transport information but it fails her as she tries to assemble bits and pieces. She is unable to make the necessary connections to complete the concept for her or for her recipient. The following analysis explores possible answers to how the gestured depiction fails her when it comes to organizing new knowledge.

A comparison of Case 1 and 2 with each other as well as with the previously analyzed explanations allow for the exploration of an emerging theory. That is, although Ellie carries gestures over to the re explanation, how they function as resources for learning in the re-explanation may depend on how they were engaged in the explanations. Understanding this can further inform how to direct instructors to use the interaction and the body to mobilize conceptual understanding.

Ellie meets with Laura in a conference room on campus two days after the explanation event. The re-explanation conversation lasts 22 minutes. Two cameras are used to film the interaction. Ellie was asked, to "share what you talked about with Bram"

(Scopelitis, Fieldnotes 8/05/2009). Once again, Ellie was not aware of my interest of study. All her gestures are naturally occurring.

Like in Case 1, the following analysis concentrates on the moments of talk and action that have to do with concepts related to the interwoven hands depiction utilized in the same, shared explanation.

Hands reveal some, but not always the right, information. Ellie enrolls the “interwoven hands” depiction in eight instances in the re-explanation. The first two reappearances work to transport information from the explanation to the re-explanation. The other six instances reveal to Ellie that her understanding of the concept is incomplete. I review three of these misunderstandings revealed to her through her use of the gestured depiction.

Reappearance 1. Ellie’s first re-appearance of the gesture depiction is reminiscent of Raya’s. It is brief and acts as a springboard to launch her upcoming re-explanation. Ellie’s re-building begins, like Raya’s, as she utters the word “so” and simultaneously lifts her hands. Together she offers a verbal and gestural signal that a physicalized demonstration is about to happen. Her gaze remains on Laura as the fingers of one hand slide in between the fingers of the other. As she comes to the word “material” her gaze drops briefly to her hands. (Again, this is similar to Raya’s actions). Such use of gaze to the recipient and then to the hands establishes joint attention on the hands, as evidenced by Laura’s gaze to Ellie’s hands (see Figure 7.28). But the hands do not offer any salient information for Laura. The depiction dissolves immediately and the talk moves to another subject matter.



	
<i>Camera 1 view of one action</i>	<i>Camera 2 view of same action</i>
ELLIE: So one thing they are trying to do is have another material.	(No talk)
<i>Ellie create “interwoven hands” depiction. Ellie’s gaze is directed to Laura.</i>	<i>Laura’s gaze is on Ellie.</i>

Figure 7.28. Ellie presents the depiction

The initial practices for this brief appearance of the gestured depiction appear to be intended to communicate information to Laura. But the communicative intent is abandoned as Ellie looks to her own hands in a lengthy pause, drops them, and moves to discuss silicon solar cells, a topic Bram used to compare to the process of construction of polymer cells.

Although brief, the take up of the gestured depiction, none-the-less, is significant. The first appearance of the gestured depiction shows the depiction travels over time and that Ellie is aware that the depiction holds some information for her re-explanation. She has just not yet recovered that information. Ellie’s first appearance of the interwoven hands” depiction is very similar to Raya’s first appearance of the gestured depiction. It is used to recall the idea of a “material”, calling up the general and basics aspects of a richer concept. The significant difference is that Ellie does not make use of the gestured depiction to pull out more information. She abandons the depiction and moves on to another topic, thwarting, for the moment, the opportunity to think through the idea.

Reappearance 2. The second appearance of the gestured depiction happens several moments later, after a discussion of silicon solar cell construction. The resurgence of the depiction serves to again to try to recall and transport information failing to emerge in the first reappearance. In the second re-appearance, the depiction is first built with the intent to communicate the information to Laura. In the process of being present, it evolves into being a depiction to not only communicate, but also to think through information at the same time.

“You have got the thing”

- | | |
|---|-------|
| 1. ELLIE: So then (.) at the tiny level (...) | |
| 2. you have the plastic solvent thing | |
| 3. that is absorbing the solar light. | |
| 4. Then you've got the thing, whatever substance it is, in between it | |
| 5. that's gonna have an electron go zup and whoop. Up it goes. (...) | |
| 6. LAURA: | Right |
| 7. ELLIE: So. | |

Figure 7.29. Transcript of talk

The re-appearance begins as Ellie utters “So then”. The use of the word “then” after “so” (unlike the first reappearance) suggests her upcoming attempt to fill the depiction with some meaning. The first actions for constructing the depiction use practices that show it is intended for the recipient. As she talks she lifts the depiction in both her own and Laura’s sightline, lifted elbows forming the depiction giving it an appearance of purposefulness. Her gaze goes to her own hands. The depiction appears in full, constructed with both hands. Next, in a quick instance, practices change, the former gestured depiction dissolves and new one appears very briefly. She pulls her hands nearer to her own body and out of the interactional space. The gesture now is a layering of her open hands over another. As she does this she voices “at a tiny level” with less volume than she used before. She returns to the “interwoven hands” depiction. There is a pause in talk as she gazes, in silence, to her own depiction (see Figure 7.30).

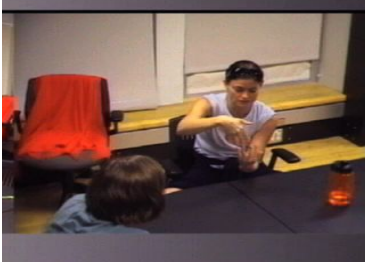


		
1. So then (.)	at the tiny level	{No talk}
<i>Lifts depiction in her sightline and gazes to it during her pause in talk.</i>	<i>Depicts “layers”. Ellie gaze to her own hands</i>	<i>Holds her gaze to “interwoven hands” depiction in the absence of talk</i>

Figure 7.30. Ellie’s second appearance of the depiction

As evidenced by her intent gaze to her hands and in the absence of talk, the gestured depiction has become a source to be visually inspected in an attempt to transport more information.

Next, the significant pause is broken. Ellie’s practices switch again and she moves from gesturing “for me” to gesturing “for Laura”. In her next move, she deliberately presses half the depiction forward into the interaction space (see Figure 7.31). Ellie’s manner of talk and gesturing changes again. The gestured depiction now is pressed closer in the interactional space. Her talk is clear and direct. She begins to add elaborations. As she utters, “You’ve got this plastic solvent thing”, her right hand references the left through pointing and traveling the length of the hand. She then slips the referencing finger in between the spaces produced by the outspread fingers of the left hand as she adds, “absorbing the solar light” (see Figure 7.31).



	
2 You've got this plastic solvent thing	3 that is absorbing the solar light.
<i>Left hand references through pointing and traveling the length of the hand.</i>	<i>Left hand continues to references through pointing. Her gaze slightly lifts to Laura.</i>

Figure 7.31. Ellie adds details for Laura

Like with Raya, the moment of inspection of the gestured depiction out of talk seems to work to recall more detailed information as elaborations propagate. She moves to create and explore the elaborations publically and in the sight line of her recipient, allowing the depiction to work both for her to think through information and for Laura as a source to communicate the information in the process of calling it forth.

The next move is yet another switch in the depictions functional use. It now becomes a gestured depiction used primarily for communicating to Laura. It is used to take a moment to highlight the depiction as the representation of the concept she is attempting to uncover. This is made evident as Ellie pauses the talk, gazes to Laura, and presses the depiction further into the interactional space, toward Laura. Her lifted elbows frame the depiction. Her body inclines toward Laura, demonstrating a full body expenditure to present the depiction for Laura (see Figure 7.32)

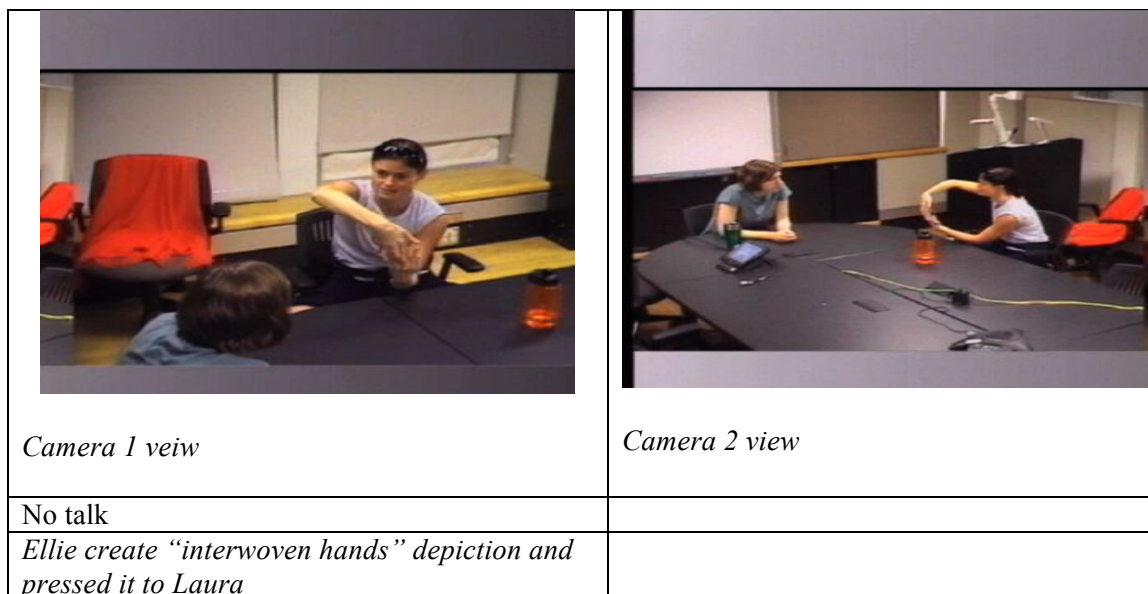


Figure 7.32. The gestured depiction communicates information to recipient

So far what the talk and action has accumulated in the first two reappearances is (1) the idea that there are certain materials, (2) one material is a plastic solvent “absorbing light”, (3) the idea that the materials are interwoven with one another, as demonstrated and highlighted in her hands and not expressed in talk. This last move of presenting the information deliberately through talk and depiction represents Ellie’s choice to make present and secure the information she has collected so far. Ellie has successfully achieved a process of transport of some, but certainly not enough information.

In her next move, Elli attempts to transport more information through talk and action. Having just completed a pattern of explanation observed when more knowledgeable others explain that include first presenting the depiction in full and making efforts for the recipient to accept it as important to the explanation, next Ellie continues the by adding details to the now built depiction, a pattern I have shown across both the experts’ explanation and Raya’s re-explanation.

Ellie, sacrificing the model of the full depiction to reference details, pulls out her right hand to reference the space between her fingers as she says “whatever substance it is, in between it”. She continues on to enact how an electron travels through the material by gliding her finger upward, over the hand that remains as material. She says, “gonna have an electron go zup and whoop. Up it goes.” She returns her hands to the “interwoven hands” depiction, giving picture to the complete “interwoven hands” depiction after its breakdown to add elaboration. The fingers settle in between the spaces of the right hands. Her gaze is directly toward Laura as she suspends talk (see Figure 7.33)



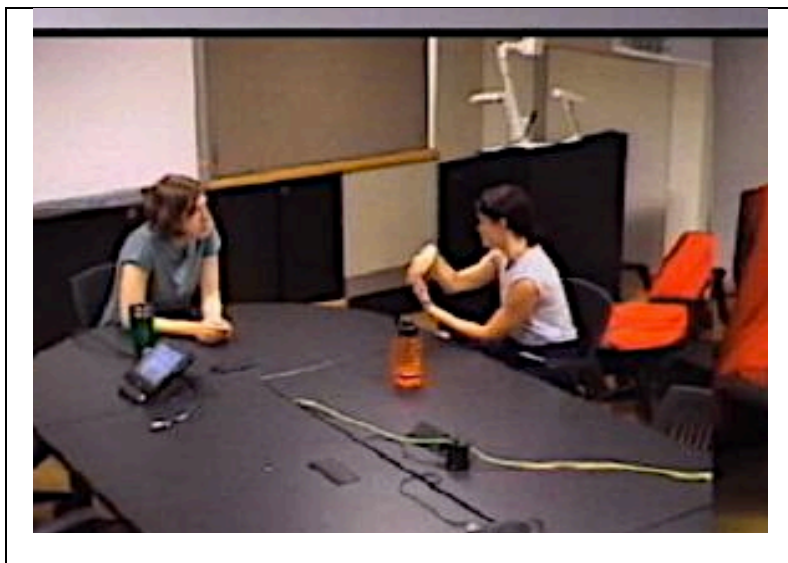
	
<p>4. Then you've got this thing, whatever substance it is in between it</p>	<p>5. that's gonna have an electron go zup and whoop. Up it goes. (...)</p>
<p><i>Fingers of right hands slip in between fingers of left</i></p>	<p><i>Left finger traces out electron. Fingers slides from wrists up to fingers and then off hand</i></p>

Figure 7.33. Ellie enacts the electron in motion

She again, in her pause of talk, assertively presses the complete interwoven hands depiction closer to Laura. Her gaze is on Laura. Laura offers a confirming “right” (see Figure 7.34), indicating that Laura recognizes the gestured depiction as part of the explanation.



6. Laura: Right

*Laura gazes to Ellie hands as “interwoven hands” depiction.
Ellie gazes to Laura.*

Figure 7.34. Laura accepts depiction as part of explanation

The presentation of the gestured depiction as illustrated in Figure 7.32 is just like the first presentation of the completed gestured depiction when Ellie, at the end of a stream of talk, presses the depiction to Laura’ and deliberately into her sight line. Both presentations act as concluding statements of what Ellie has attained so far. She has added to the concept that there is another substance in the material. She, however, is aware that she does not know what that substance is. She does know that the substance is “in between” the plastic solvent has something to do with making the electron go up. Important to notice, is that Ellie’s description and demonstration of the electron motion is up, although Bram (as well as Raya) described it and demonstrated it as going down.

Ellie moves on. Her gaze settles on her own hands as she pulls the depiction closer to her own body. As she gazes to her, she says in a quieter tone than the preceding talk, “So” (see Figure 7.35). The word “so” serves, not as a signal for an upcoming demonstration as it has before, but rather as a conclusive statement that her re-

explanation has reached an end for now. Her hands dissolve out of the depiction and she moves to another topic of talk.

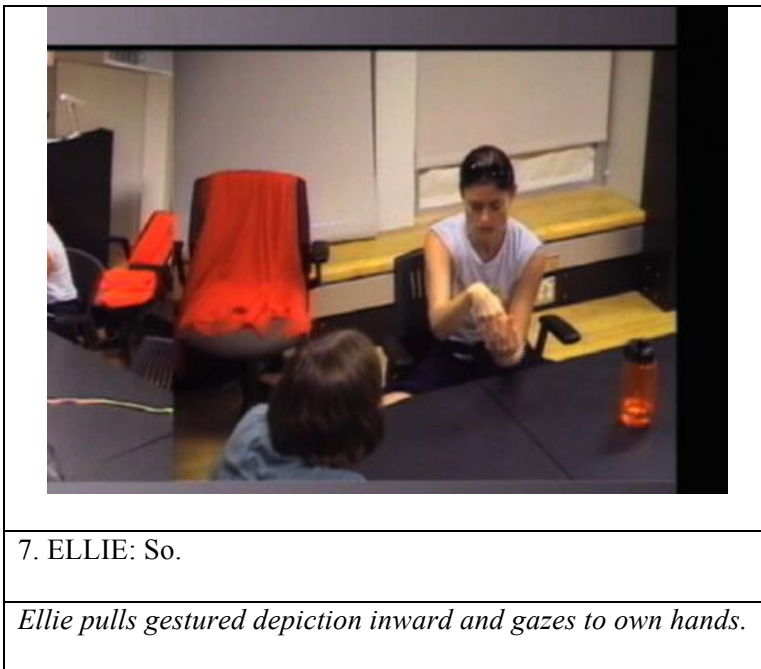


Figure 7.35. The depiction becomes a depiction for thinking

In summary, this second reappearance of the gestured depiction is, at times, reminiscent of Raya's. First, there is an interaction between thinking "for me" and communicating "to you" that motivates the speaker's attempt to transport and assemble information. There is also an accumulation of information as prior talk and action begets further talk and action and adds to the concept. There are also slight inaccuracies and gaps of information present, as were with Raya in the beginning of her re-explanation.

Looking at Ellie's first two reappearances of the gestured depiction together, there appear to be not only significant patterns of similarities, but also some significant differences between Raya and Ellie's gestures. Similarities include, that Ellie, like Raya, recognizes that the depiction is relevant to the explanation and demonstrate awareness that critical information is held the depictions she creates. Like Raya, Ellie presents the

depiction in its entirety and continues to add on elaborations. Another similarity is that, like Raya, Ellie moves between serving as explainer communicating information to Laura to learner trying to transport and assemble information for her own understanding. The gestured depiction in both cases dynamically slips between serving primarily as a depiction “for me”, to recall information and a depiction intended “for you”, to communicate information. The significant difference is that, unlike Raya, when Ellie reaches a level of uncertainty she turns to another topic of conversation. Unlike Raya, in the 5 minutes where the two re-appearances take place, Ellie has scattered her talk and action across 5 very different topics that were originally presented sequentially across a 40-minute explanation.

In the next three instances the gestured depictions render confusion. Like for Raya, gestures accumulate information. Following I illustrate, that unlike for Raya’s depictions, Ellie’s gestured depictions accumulate misinformation, thus interfering with a sufficient assembly of information. The following analysis suggests that her misunderstandings are the result of unsuccessful assembly.



Misunderstanding 1. Ellie’s following misunderstanding is a result of connecting the wrong bits and pieces called forth in her talk and action.

“Maybe”

- | |
|--|
| <ol style="list-style-type: none"> 1. I think he was saying these were like (..) 2. 10 nano (.) atoms (.) nanometer apart 3. Maybe it’s just atoms. |
|--|

Figure 7. 36. Transcript of talk

When Ellie returns back around to talk about “the material”, she extends a finger as she says, "I think he was saying that these were like (.) (see Figure 7.37)

	
I think he was saying these were like (.)	Maybe it's just atoms
<i>Ellie extends index finger and gazes to it</i>	<i>Ellie maintains extended finger and gazes to Laura</i>

7.37. Ellie gazes to her hands; hands become a thinking tool

As she says, “I think he was saying that these were like” Ellie’s gaze goes to an extended finger as she travels back to the explanation event to recuperate information. (She is likely recalling Bram’s similar use of the finger to explain measurement). Here the depiction is serving as a depiction for her own thinking.

The information she pulls from her depiction is not exactly what Bram communicated. In the pause in talk she keeps gaze on her finger as she tries to recall a measurement of distance. Her talk shifts back and forth between uttering the terms “nano” and “atom” in relationship to the number “10”. She hesitantly settles with, “Maybe its just atoms”. Her gaze goes to Laura as she speaks, denoting she has reached her conclusion. But her conclusion is not like Bram’s. Bram, in fact, reports the unit of measurement as 10 nanometers a he points to his finger, not 10 atoms. Ellis is likely linking up previous talk from the explanation event with the incorrect gestured depiction. Bram explains the length of a nanometer as roughly equal to “2 to 10 atoms, depending” as he slides his hands laterally as palms face one another.

Misunderstanding 2. Again Ellie turns to her hands to relieve confusion - a telling move in itself in that she has deemed the hands as a source of information to

support her thinking. Her hands, however, again, render incorrect information. There is a mismatch between the gesture she performs and the information that was attached to it in the explanation.

“I am a little unclear about that”

1. ELLIE:	Uhm but I think he was saying they were using aluminum
2.	And I think he was saying this one (.)
3.	is the material that's attracting,
4.	(..) Is it the shape of a soccer ball thing?
5.	(...) atoms (..) an arrangement of dodecahedron (..)
6.	or something like that.
7.	Actually, I am a little unclear about that so I actually shouldn't say too much about that.

Figure 7.38. Transcript of talk

Ellie seems to create a slightly adapted version of the interwoven hands depiction. It is slightly different in that, unlike other instances, across the explanation and the two re-explanations, Ellie’s thumbs touch one another. She holds the depiction near her, her gaze dropping down upon it. In an attempt to transport information using the depiction she says, “ Uhm but I think he was saying they were using aluminum.” She restates her realization with more specificity as thumbs detach from the form and she pulls the right hands slightly away from the left (see Figure 7.39).

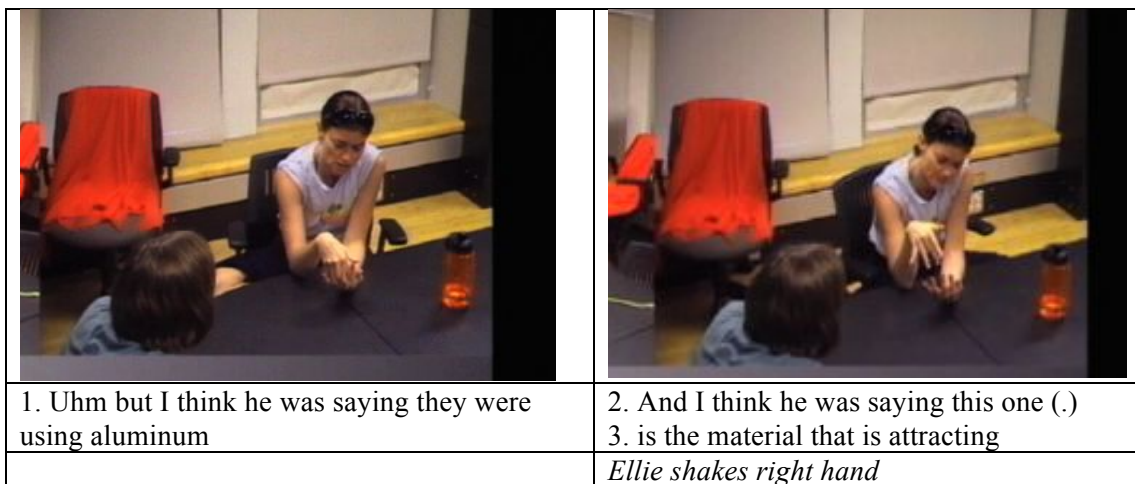


Figure 7.39. Depiction is used to resurrect information to clarify misunderstanding

Once again, Ellie links up incorrect information. First, there is indeed a material that attracts energy in polymer solar cells but Bram does not define it as aluminum. Aluminum is used to discuss the mechanism of silicon solar cells; not polymer solar cells. This misunderstanding is likely emanating from the gestured depiction that is combining two topics of talk. The interwoven hands depiction, with the thumbs touching appears to be the collapsing of two gestured depictions; one that is, in fact, the interwoven hands depictions to reference the material of polymer cell layers. The other, a depiction Bram creates in the explanation that refers to the dodecahedron shape of a silicon molecule. Bram likens this to a soccer ball (“You can think of it as a soccer ball”) (Scopelitis, Fieldnotes, 8/10/2009).

As the hands offer confusion, they also provide her with an assessment of her latest statement. Ellie recognizes she may be confusing two shapes as she more clearly creates a ball-like depiction with her only fingers slightly interwoven and thumbs touching. She rounds out the shape more, giving it a volume. She asks herself, “Is this the shape of the soccer ball thing?” (see Figure 7.40). It is important to recognize that the hands that not only create her confusion but also uncover her awareness of her confusion.



Figure 7.40. Depictions are used to differentiate between concepts

Ellie concludes her activity of transporting and her attempt to assemble with the evaluation that she is not able to reach a sufficient conclusion, “Actually, I am a little unclear about that so I actually shouldn't say too much about that.” As she speaks, her hands close in on one another, one holding the other, as if to stop them from “talking” (see Figure 7.41). Although not a realization getting her closer to understanding, the realization she comes to is produced with the hands and helps her assess her level of understanding as insufficient.



7. Actually I am a little unclear about that so I actually shouldn't say too much about that.

Ellie folds hands in on one another and depictions dissolve

Figure 7.41. Depiction helps conclude there is missing information

The hands give her feedback. She realizes the feedback they give her is faulty. This should not be taken as a dismissal of the hands as resources for information. For they certainly are providing her with the opportunity to assess her own understanding as uncertain. Here is an example of how gestures as support to uncover information can break down. Ellie's hands in the shape of the "interwoven hands" (see Figure 7.38) depiction are confused with hands that are in a similar shape to show a dodecahedron. Her hands transport information but the wrong information.

As gestural action in partnership with talk summon information as they feed off one another, creating an interactive polyphonic emergence of information, the unfolding of bits and pieces may not accurately reproduce the original explanation. Raya engages in the same process of pulling out information as Ellie does, however, she recognizes her assembly as sufficient while Ellie recognizes it as insufficient.

Misunderstanding 3. In the next example, Ellie constructs the depiction for thinking again in an attempt to transport and pull out information. Some information surfaces but it cannot be expanded on.

“ I got a little confused”

1. Uhm I feel like there was something else. Oh
2. So I got little confused about how they actually
3. get this other material fitting into these spaces.

Figure 7. 42. Hands help conclude there is missing information

She gazes to her hands and says as she creates the “interwoven hands” depiction, “I feel like there was something else”. The hands trigger a question about how “they actually get this other material fitting into these spaces”. But no answers come to her as she gazes to her hands. She drops the effort, as well as the depiction, and moves on to another topic (see Figure 7.43).



1. Uhm I feel like there was something else. Oh
2. So I got little confused about how they actually
3. get this other material fitting into these spaces.

Ellie holds gesture through out talk. Gaze remain on hands

Figure 7.43. Depiction reveals misunderstanding

Both Raya and Ellie, engage gestures to build off one another to uncover and connect information. Raya's accumulation of ideas through her talk and action mobilizes her toward understanding, Ellie moves her to confusion. None-the-less, the pattern of processes is the same, it just that the material is not right. The analysis thus far supports the idea that gestures serve a value. It also suggests that the value must be cultivated and organized to be of the most effective use.

In the process of re-explanation, Ellie has learned that she has more to learn.

Ellie seems to be aware that she is unable to assemble higher level aspects of the concept, although she has attempted to through talk and action. In a final (re) appearance that occurs at the very end of the conversation, Ellie offers a summation of the research Bram is conducting. The "interwoven hands" depiction is used to express what she knows about the entire concept, which is not much more than what she started with. She looks to her hands and as she says, "I think he is really involved with figuring out how to make these two things fit together" her gaze is to her hands. Once she says this she presses the "interwoven hands" depiction toward Laura. She stops there and the depiction does not appear again (see Figure 7.44).



	
<p>He's really, I think he is really involved with</p>	<p>figuring out how to make <u>these two things</u> <u>fit together</u></p>
<p><i>Create depiction. Gaze to own hands</i></p>	<p><i>Presses depiction into Laura's interaction space</i></p>

Figure 7.44. Ellie presents the final depiction to Laura

By the end of her re-explanation, all Ellie's talk and action appears to get her back where she started. What she knew at the beginning is the same as she expresses at the end – there are materials that work together to make up the polymer solar cell. But does Ellie's explanation really get her nowhere. Certainly not! The use of her hands gains her the awareness that her learning is not complete and puts her in a position of readiness to learn more. This, too, is a level of learning and a process toward understanding that is achieved with the hands. The question that emerges is how to develop the gestured depictions to achieve understanding, as Raya did, rather than contribute to misunderstanding, as was so with Ellie. The answer may exist in the interaction between the more knowledgeable other and the learner, as it provides guidance on how to make use of the depiction mobilize understanding.

Case 2: What has been gained from the analysis? Case 2 continues to reveal that gestured depictions built in the explanation event matter to the learner so much so that they are carried over to the re-explanation. It further reveals, that although carried

over, the value of their use can range from transitioning knowledge to assessing lack of certain information.

As Raya's re-explanation is an exploration of the concept through her hands that gains her more information, Ellie's is an exploration of the concept through the hands that ends up leaving her with not much more detail than what she started with. Ellie's use of the gestured depictions reveals that her learning is still transitioning. She is able to recognize her misunderstandings through her gestured depiction but is unable to clear them up. That is not to say she does not gain from the use of the depictions. The information she gains from the use of her hands is that she learns she lacks much of the detail she needs to really understand (and explain) how polymer solar cells work. This is important because it shows that as gestured depictions are taken up they can be used as resources to assess a learner's own level of understanding. It is not just that the gestures create confusion, more importantly they give her insight into her misunderstandings. This, in turn, can shape the next steps to achieve sufficient learning.

A comparative analysis of the cases brings forth the question of why is Ellie's re-explanation different than Raya's. Ellie recalls quite a bit of information but is unable to make the necessary connections to complete the concept for her or for her recipient. As Ellie transports gestures over to the re-explanation, I question *if* and *how* they function as resources for learning in the re-explanation may depend on how they were engaged in the explanations. Does how the gestured depiction engaged in the interactive explanation, inform how they will be of use in later re-explanations? Following I explore this emerging theory.

Discussion and Implications: Locating a Relationship to a Recipient's Gesture Use in the Explanation to its Functional Value in the Re-explanation

In the discussion to follow, I suggest that Ellie's experience with the gestured depiction during the explanation of the configuration of polymer cells affects her re-explanation. I isolate the discussion to only her re-explanation of polymer solar cells. Ellie's earlier re-explanation of previously discussed silicon cells was clear and detailed. It is not until Ellie moves to Bram's research for replacing silicon material with polymer material that her re-explanation breaks down.

Interestingly, it is when Bram moves to the explanation of how polymer cells can be constructed that Ellie's interactional participation decreases, while Raya's increases. If interaction is important for instilling the value and meaning of gestured depictions for explanation, as the prior studies have suggested, Ellie's decrease in interactional involvement during the discussion of polymer cells may point to a source of her confusion in her re-explanation.

Ellie's interactional involvement decreases as she begins to assume the role of the more knowledgeable learner while Raya is revealed as the learner in need of more explication. I suggest that these roles the learners assume affect their interactional activity. To explore this theory, I return to the explanation and provide examples of instances that support where identity shifts parallel the level of interactional involvement.

Ellie becomes securely situated as the more knowledgeable learner and Raya as the less knowledgeable learner by the time Bram explains polymer cell configurations. These identities were established over time and across participants. In fact, they were set in motion at the onset of the conversation when Raya declares she remembers nothing

about her science classes and Ellie states that she “really enjoyed science” and thought, at one point, she might go into the field [Scopelitis Field notes, 8/03/2009]. These perceptions of self as certain level of learner in the science are further confirmed. Ellie’s higher level of confidence in the subject matter is evident in her quick pick up of understanding in the earlier explained use of silicon for solar cells. It is apparent in her often-executed head nods and her use of terms such as “proton” and “electrode” before Bram uses them. She becomes viewed as the learner who was “getting it”. As I showed in Study 2, Raya supports this identity when she presents the “interwoven hands” depiction to her and asks, “Did you follow that?” and then proceeds to pose a clarifying question to both Bram and Ellie. Bram also contributes to Ellie’s positioning by directing his gaze and the gestured depiction for explanation more often to Raya than to Ellie for it is Raya whose gaze drifts and brow furrows while it is Ellie who nods confirmingly and confidently interjects comments such as “ok”, “right”. Ellie also contributes to her identity by offering refining information as she gestures over Raya’s depiction and very clearly explains the position of electrons and protons. This gains her Bram’s affirmation that she is correct. Consequently Raya earns the identity as less knowledgeable learner and leans to both Bram and Ellie for clarification. In turn, Bram directs much of the explanation gazing to Raya.

It is perhaps because of these established identities that Raya more often enacts the gestural demonstrations Bram performs as he explains. For example, as he touches his finger to describe the 10 Nano-meter distances, Raya also touches her finger. Ellie does not. As he presents half the “interwoven hands” depiction as he explains the detailed process of how the material is fabricated, Raya too performs this same action

directly after him. Ellie does not. As Bram describes how the material “attracts” the electron, Raya performs her own enactment of attraction as she pulls her hands in toward her. Ellie does not. It is likewise likely that these established identities also shape Ellie’s participation in the explanation of polymer solar cells. During the detailed explanation of the mechanisms of how polymer solar cells work, Ellie spends more time observing Bram’s (and Raya’s) gestures from the sidelines with confirming head nods. She does not pick up the gestures in the stream of explanation nearly as much as Raya does, and nor does she use them as manipulable tools for experiencing and organizing new knowledge, as Raya does.

In the segments for the explanation of polymer cells, she picks up the depiction once to add clarification to Raya’s question and she picks it up three more times in the process of Bram’s explanation. Once she lifts it as a failed attempt to gain the floor. (Bram does not see it because he is attending to Raya). Ellie takes up the “interwoven hands” depiction two other times in the stream of the explanation of polymer solar cells and uses it to “mark” and record knowledge earned as she holds it briefly and near her own body and out of the stream of talk. It is an important point to note that all her enrollments of the gestured depiction are only replications of the shape of the interwoven hands; there are no other auxiliary gestures that contain more details about the material and the mechanisms through which polymer material can create energy from the sun.

Another important point to make is that even after Bram’s detailed explanation of how polymer solar cells work, Ellie’s dominant experience with the “interwoven hands” depiction is the re-making of the depiction in its full, two-handed construction, acting as a stand in to reference the broad ideas that two materials fit together. She constructs this

copy of the “interwoven hands” depiction several times. As it always refers to the concept in general (i.e. “These guys”, “This process”, “These materials”), its construction with talk does not reveal an understanding of the entire process of a theory of how polymer solar cells work. It seems important to note that, even after exploration in the re-explanation, this is exactly the conclusion Ellie comes to in her final statement of the concept in the re-explanation – nothing more. All she shows she knows is that two materials fit together and this has something, she is not quite sure what, to do with how polymer cells work.

I suggest that Raya having assumed an identity as less knowledgeable learner initiates her to use the explanation to catch up. This, in turn, gives her more opportunity to interact with Bram and the depiction he deems valuable for explaining the concept. Her using her hands and body under the watchful eye of the expert may very likely earn her more resources for thinking through, in the later re-explanation, in the absence of the expert. If so, this suggests that the more opportunity for embodied action under the guidance of a more knowledgeable other shapes a more refined learning experience that brings the non-expert closer to the discipline.

That is not to say, Ellie’s use of the gestures in the re-explanation is trivial. In fact, it is significant to her further learning. It shows that she deems them as valuable. And they are. They help reveal her misunderstandings, putting her in a position of being ready to learn more. But I cannot help but suspect that if her experience in the explanation of polymer cells was different and she took up the depictions as a thinking tool to work through details in the presence of the expert that there would be less confusion in her re-explanation. The data suggests that the use of gestures as depictions

to explain and work through concept across expert and learner give more opportunity for developing understanding together.

I return to the idea of disciplining perceptions – the idea that an expert guides a learner towards ways of seeing and understanding in a discipline through the use of the body. Bram certainly assumes this responsibility as expert explaining for non-experts. His hands become one of the resources he uses to guide learners through the concept. He uses them often. They are not simply presented as depictions to complement talk. They are actions that demonstrate and communicate the complexities of the ideas he shares. Raya, identified as the less knowledgeable learner, allows her perceptions to be disciplined by actually practicing how to understand in the stream of explanation. As a result, I suggest that she enters in to the re-explanation knowing full well she is a learner and continues to use her body, as Bram guided her to do, as a way to support her thinking. Ellie, on the other hand, was not given this opportunity in the explanation about polymer cells.

Knowing that Raya and Ellie both recognize the body as important resources for learning so much so they carry gestures with them over time is just a start into investigating the complexity of gesture in teaching and learning. Understanding *how* and *why* and *when* gestures can function as strategic resources to add more to learning are questions well worth attending to. The theory that emerges from this analysis is that a learner's interactive experience across the use of gestures in the explanation affects the further development of understanding in the process of re-explanation. This idea offers a launching point from which to further investigate how we can take full advantage of gestured depictions for explaining and understanding concepts in interaction.

CHAPTER 8
STUDY 4: AN ANALYSIS OF COLLECTIONS OF DATA: COMPARING FOUR
CASES ACROSS THE EXPLANATION AND RE-EXPLANATION EVENT

Introduction: The Persistence of a Gestured Depiction Over Time

The analysis of brief segments from an expert explanation (Study 1) to the analysis of an extended explanation (Study 2) has served to reveal ways in which experts and non-expert use gestures and the body to jointly build understanding. The analysis of two re-explanations (Study 3) showed that gestures can be taken up and carried across time and used by the learner in re-explanations. Now Study 4 aims to apply these findings further as I examine cases from across the data in which experts explain a concept to a non-expert and then the non-expert re-explains to another.

I first extend findings from Study 3 and show gestures often do travel across time with the learner. I further explore the idea emerging in Study 3 that the way in which gestures travel across time is shaped by the way they were used in the expert explanation. I suggest that it is not enough that gestures simply appear in the teaching and learning episode. Rather, whether gestures support learning depends on how they are used in the explanation.

To add more to prior findings that gestures can travel over time, I present a series of examples representative of the data demonstrating that gestures travel with the learner into the re-explanation event. To shed light on to what extent they serve the learner and the interaction, I analyze a collection of cases of experts explaining concepts to non-experts and then look to the corresponding non-expert re-explanations. In this “analysis

of collections” I concentrate on when, how, and for whom gestures function to extend understanding of the role the body plays in teaching and learning.

Data and Analysis

The data emerges from Phase Two of the data collection process in which experts explained STEM concepts to non-experts. The non-experts, in turn, re-explained the concept to another 2 days later. The data corpus from Phase Two consists of 11 hours of videotaped recordings yielding six experts-as-explainers participating in a total of 16 expert explanation conversations. Experts explained a concept of their choice between 2 and 4 times. The focal concept, chosen by the expert was not always the same across experts’ explanations.

For the purpose of this project, I have discarded threads made up of the explanation event and the re-explanation event that did not meet certain criteria. These included 3 threads, two of which the non-expert had extensive previous knowledge of the concept explained, and the other in which the non-expert was aware of the intentions of the study. I have further reduced this data corpus to collections of threads that are most representative of all threads.

The process of analysis follows the approaches to analysis used in the prior three studies. The analysis takes a micro-ethnographic approach of videotaped interactions in which I employed a constant comparative analysis of talk and action, turn-by-turn (turns both in talk and gestures). This process allows for a close and iterative investigation of how the hands and body are made of use in interactive explanations and re-explanations for the teaching and learning of STEM concepts.

As the project concentrates on gestural action that invokes tangible objects and performable actions in interaction, I focused primarily on depictive gestures. I compared gestures used to depict information in the original explanation event to the gestures used to depict information in the re-explanation event. I noted gestural practices in the re-explanation that corresponded, related to, or contradicted gestural practices used in the explanation. I set moments of the use of gestured depictions in an experts' explanation against similar moments of the use of same gestured depictions in the non-experts' re-explanation. I subjected these to sequential analysis to further understand how gestured depictions are used across time.

The Findings

The following general categories of phenomena have emerged from extensive analysis of expert explanations. (1) The expert's use of the gestured depiction develops out of the perceived sense of a recipient's need to understand the concept, a sense that is demonstrably built up over the course of the interaction. (2) Recipients take-up the expert's gestured depictions to extend understanding and anchor new knowledge in the course of the explanation. Both the explainer and the recipient use gestures to correct the learner's misunderstanding (in response to the learner's gesture). (3) Gestured depictions are used by all participants for thinking through concepts together as they are volleyed back and forth between participants and treated as both cognitive and communicative resources in the pursuit of building understanding together. (4) Finally, gestured depictions are used by both the explainer and the recipient to steer the interaction toward the shared goal of achieving understanding. These collective uses of gestured depictions

to explain concepts in face-to-face learning arrangements demonstrate that gestures are flexible multi-functional, multiparty resources in interaction that contribute to the achievement of joint understanding.

Categories of phenomena first revealed in Study 3 are present in the following analysis of a collection of cases in which a non-experts re-explain concepts to other non-experts. The findings include (1) gestured depictions used in explanation carry over into a non-expert's re-explanation, and (2) although still engaged as communicative tools, thinking tools, and tools to direct interaction, the distribution of these functions shifts as the learner becomes explainer. That is, the gestured depiction shifts to serve more prominently as a depiction for thinking.

Study 4 allows for further application of these categories of phenomena across more cases. I approach Study 4 with the intent of investigating how and to what extent these patterns re-occur. I engage Study 4 with an interest in examining what contributes or takes away from the use of gestured depictions as tools for a learner's developing understanding over time. This final study of my dissertation project draws together and gives credence to findings that shed light on how people make use of gestures and the body to accomplish teaching and learning in interaction and across time.

Looking Across Cases: Gestures Travel Across Time with the Learner

The data were used to answer the question: Do gestures built in explanation travel across time with the non-expert to a conversation in which the newly learned concept is re-explained to a less knowledgeable other? In short, the answer is – YES, they do!

Example 1: Nancy carries over Mark’s gestured depictions. Mark uses gestured depictions to explain how a machine he has created separates and distributes proteins. Nancy carries the gestured depiction he uses over into the re-explanation. Both use the same gestured action in which the hand extends forward from the body as fingers spread. The action is attached to the word “spray” (see Figure 8.1).

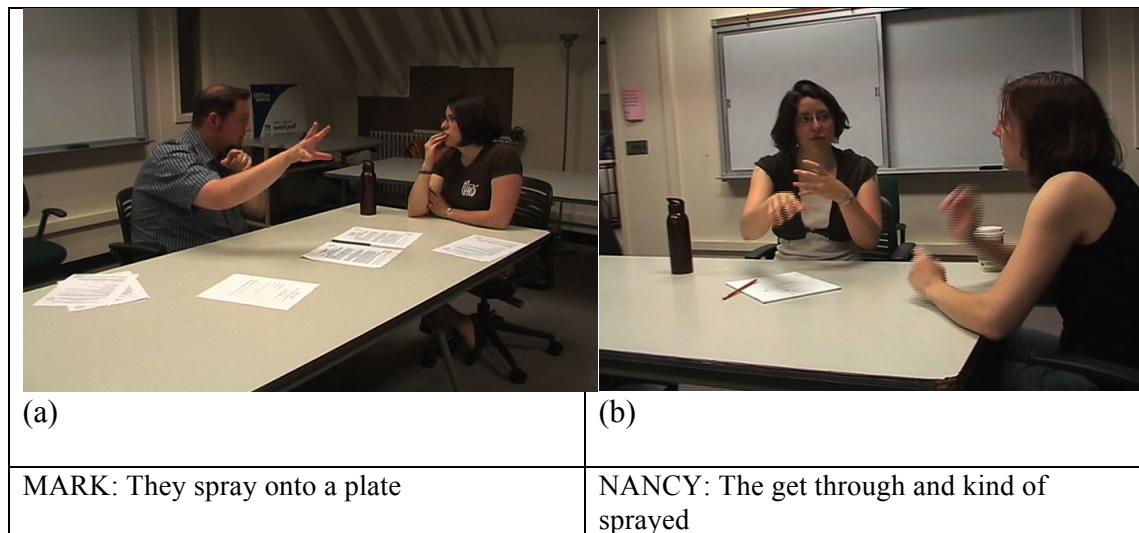


Figure 8.1. Gesture appears in explanation (a) and in re-explanation (b)

Example 2. Sansa carries over Gary’s gestured depictions

Gary is explaining how protons collide as he describes his research with the Large Hadron Collider in which physicists send protons at near light-speed around the 17-mile-long underground ring beneath the earth. The protons collide head-on to create explosions that give rise to new particles. His hands begin in an open position about the width of his own body. He brings them together so his hands and fingers are touching. The enactment is performed with directness and force. Each of Gary’s presentations is performed for the recipient (Sansa) as his body is positioned facing her and gaze goes to the recipient (see Figure 8.2).

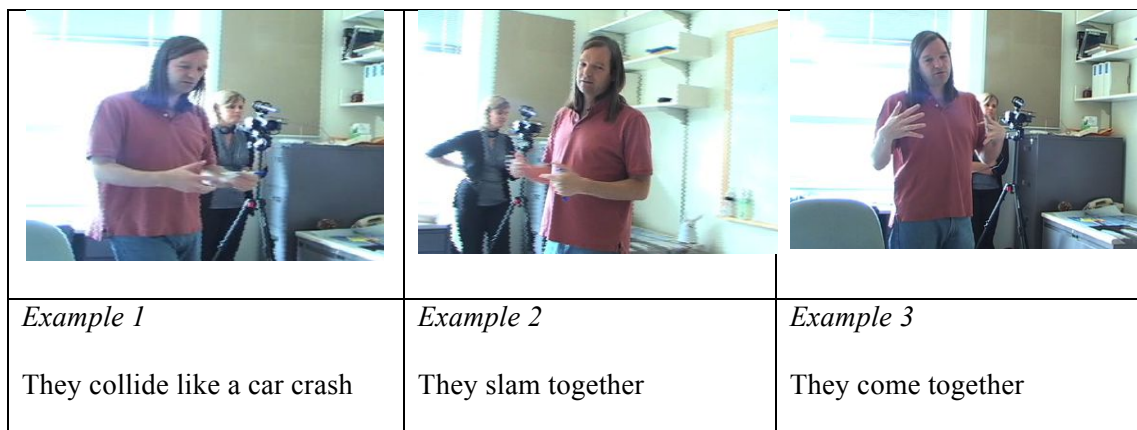


Figure 8.2. Gary performs “colliding gesture” in explanation

Sansa does not perform this gestured depiction in the explanation but it does appear in her re-explanation. Like Gary, her hands begin apart and then glide into one another and connect as she talks about protons colliding (see Figure 8.3).

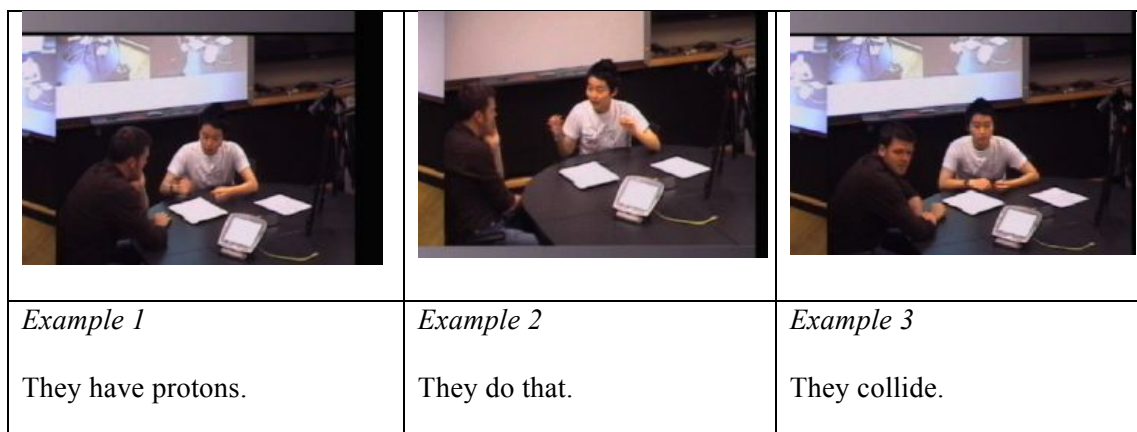


Figure 8.3. Sansa performs “colliding gesture” in re-explanation

Example 3. Erica carries over Bram’s gestured depictions. Bram explains that there are layers to polymer solar cells. As he does this, he slides one hand over the other (see Figure 8.4)

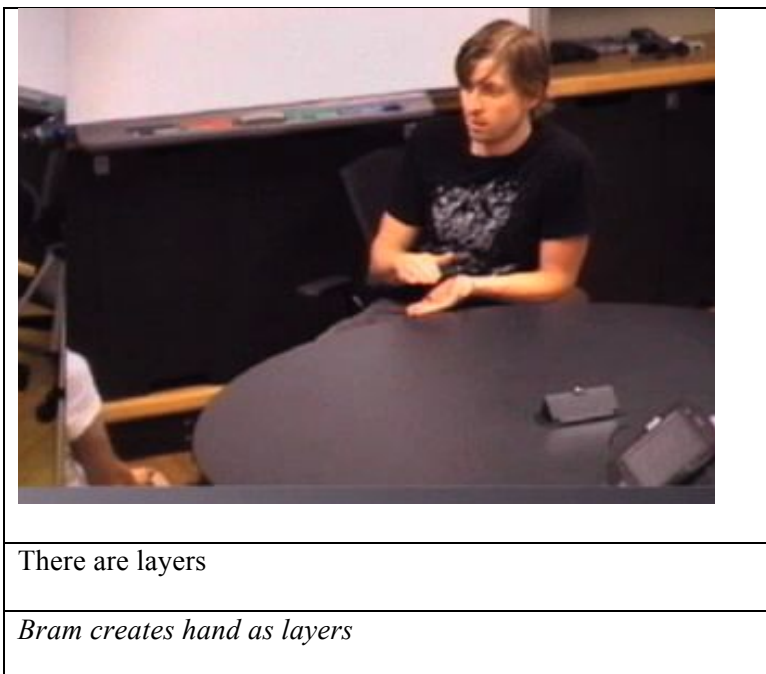


Figure 8.4. Bram performs “layering” gesture in explanation

In the re-explanation, Erica begins to talk about the idea of layers as she creates the gesture for layer performed in the explanation (see Figure 8.4). She pause and says, “They’re layers...wait” engaging the gesture as depiction for thinking that works to transport information. She continues and repeats the gesture as a communicative tool as her gaze goes to the recipient and she increases the gesture’s size (see Figure 8.5).

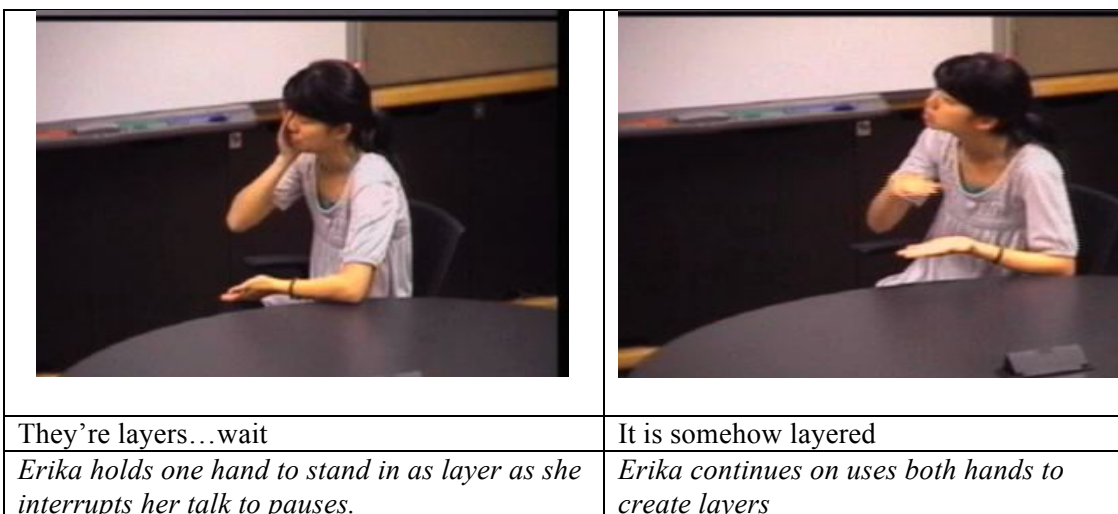


Figure 8.5. Erika repeats “layering” gesture in in-re-explanation

Example 4. Samantha carries over Mike’s gestured depictions. Mike explains the definition of the light spectrum as being an “ordered distribution of energies.” As his left hand remains stable, his right hand moves away from the left in gradated movements, as if isolating section sequentially. Mike performs this 8 times in the explanation when he discusses “energies” and “spectrums”. Samantha takes up the depiction in the explanation event (see Figure 8.6) after he has discussed the spectrum of light in a rainbow as energy when she says, “I never thought of rainbows as energy”.




		
<p><i>Example 1</i></p> <p>MIKE: An ordered distribution of energies.</p>	<p><i>Example 2</i></p> <p>MIKE: Think of a rainbow. We can see energies as light.</p>	<p><i>Example 3</i></p> <p>SAMANTHA: I never thought of rainbows as energy</p>
<p><i>Left hand remains stable as right hand moves away from left in gradated movements</i></p>	<p><i>Left hand remains stable as right hand again moves away from left in gradated movements</i></p>	<p><i>Both participant maintain shape of hands as recipient asks a question</i></p>

Figure 8.6. Mike creates depiction in explanation

In the re-explanation, Samantha performs the gesture partnered with the exact words Mike used to define spectrum. She repeats the same gesture as a clear communicative tool for her recipient as she lifts the gestured depiction in his sightline and shifts her gaze to him (see Figure 8.7).



	
<i>Example 1</i>	<i>Example 1</i>
SAMANTHA: An ordered distribution of energies	SAMANTHA: Energy is a ordered
<i>Left hand remains stable as right hand moves away from left in gradated movements</i>	<i>Left hand remains stable again as right hand moves away from left in gradated movements.</i>

Figure 8.7. Samantha creates depiction in re-explanation

These examples just presented support the assertions revealed in Study 3. That is, gestured depictions created in the explanation can travel across time with the learner to a re-explanation. This gives further evidence that an explainer's gestured depictions can matter to a learner so much so that they carry them with them. Questions emerge out of this finding. First, as not all gestures travel across time with the learner, how do some persist while others wither away? Also, as gestured depictions are carried over into a re-explanation, what can additional analysis tell us about the functional role gestured depictions serve the learner-now-as-explainer? Further, how these functional roles cultivated across interaction and across use?

A Micro Analysis of 3 Cases: Discerning What Makes a Gestured Depiction of Use Across the Explanation and the Re-explanation Event

In what follows I look at three cases each made up of an explanation event and the subsequent re-explanation event in more detail in order to distill some of the differences

across cases understand when and how gestured depictions travel and how non-experts' make use of the functional affordances of the gestured depictions for learning across the explanation and re-explanation. I present the analysis of three cases in the chronological order in which the data was collected. This important to note because in the process of collection I continued to re-design the arrangements in order to yield the likelihood of certain things happening that I wanted to analyze, such as interaction between explainer and recipient. I moved conversations out of expert's offices and into conference rooms, a student lounge and café. To encourage a conversational exchange and discourage a lecture-like format, I told participants to think of their conversation as akin to a casual dinner conversation (Scopelitis Field notes, 06/08/2009). Non-experts were told they could ask questions throughout the discussion.. Case 3, as well as the case in which Bram explains the concepts to Raya and Ellie and they re-explained to another (discussed in the previous Chapters), are a result of this new design. Once again, in all cases analyzed, participants were not aware of my interest in gestures and were not encouraged to gesture. Thus, all gestures are naturally occurring. Comparison across these evolving arrangements offer insight into the conditions in which gestures are successfully, enrolled and mobilized.

Case 1 and Case 2 differ from Case 3. In Case 1 and 2, explanations took place in the experts' offices. Like in all cases, experts received instruction to explain concepts to learners in a way for them to be able to re-explain it to another. Non-experts were told they were going to re-explain the concepts to another. In Case 1 and Case 2 learners sat in the offices while experts stood in front of white boards/chalk boards and explained. In Case 3 the conditions were somewhat different. The explanation took place in a neutral

conference room where participants were seated across from one another. These conditions tended to establish arrangements that resembled a lecture like format.

In the cases to follow I compare how gestures were used in the explanation with how they are used in the re-explanation to explore what criteria may make up effective uses of gestures in explanation events that extend to the re-explanation event and support learning.

Case 1: More than just present: A case suggesting that lack of interaction affects the extent of the take up of the gestured depiction in and across events.

Settings.

Explanation: The expert's office

Re-explanation: Conference room

Concept. Higgs field, a theory in particle physics that explain the genesis of inertial mass.

Participants.

Gary: Expert -Professor of Physics

Eliza: Non-expert. Graduate student in history

Gestured depiction: "Hands as forces "

Lia: Confederate recipient of re-explanation

Case 1 suggests that in order for gestures to serve in the development of understanding a concept the gestured depictions need to be more than just present. They also need to be for the recipient, presented as explainer and recipient face one another. Case 1 shows that limited interaction between explainer and recipient can affect the re-use of helpful gestures in the re-explanation. Conversely this suggests that a rich

component that renders gestures as viable tools to support understanding may be the interactivity between explainer, recipient as well as with the gestured depiction.

The explanation. Gary is explaining the Higgs Fields, a theory in particle physics that explains the genesis of inertial mass. He builds the theory through the use of images he draws on the board and animates with gestural actions. The concept is built step-by-step across modalities as he presents the basic idea and then adds elaborations. The elaborations are added either by drawing or gesturing. He begins to describe the concepts of force in relationship to mass by creating a metaphor of sailboats propelled by wind. Force is first presented in this metaphor as “a wind”. He draws an arrow on the board and labels it “wind”. He puts the marker down and enacts the motion of wind (see Figure 8.8). His gesture is large. He uses gaze shift between his drawings, his hands, and his recipient. He pauses once the talk and action is complete and looks to Eliza, indicating that the building of the concept across resources is meant for her to attend.

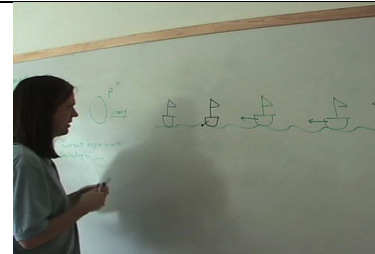
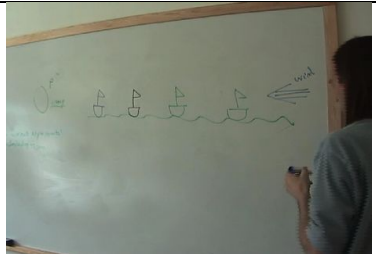
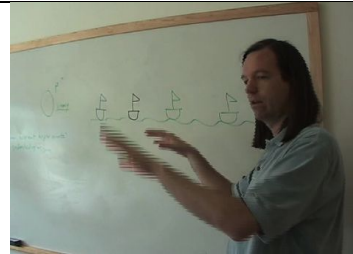
		
You have sailboats on a lake	You have a wind	Here is your wind over the lake
<i>Draws sailboats on board</i>	<i>Draws arrow and labels it “wind”</i>	<i>Enacts the motion of wind. Shifts gaze from board, to hands to Eliza.</i>

Figure 8.8. Gary uses depiction to describe force in explanation

The lateral sweeping gesture accompanies his talk of force across multiple times. The first time it is performed largely with two hands. After that, the gesture is no longer performed with two hands. It is only performed with one hand. Each time the gestured

depiction is employed it is coupled with images on the board. Gary performs these sweeping gestures three more times over the image in this two-minute segment as he builds the concept. He adds elaborations through gestural action as his hand(s) enact the wind over the board and his talk gives detail to his actions. (“Think of the wind as forces”; “Force gets particles to interact”; “Accelerations are all different due to the wind, the force” see Figure 8.9).


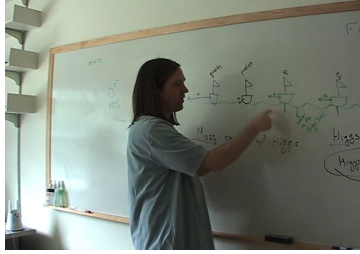

		
<i>Example 1</i>	<i>Example 2</i>	<i>Example 3</i>
Think of the wind as the forces	Force gets particles to interact	Accelerations are all different due to the wind, the force
<i>Moves hand back and forth laterally over the board and then shifts gaze to Eliza.</i>	<i>Slides hand across board as he says “force”</i>	<i>Moves hand back and forth laterally over the board</i>

Figure: 8.9. Gary enacts force with sweeping lateral gestures in explanation

In all 4 presentations, Gary’s gestures are large, displayed in Eliza’s field of vision. Gary turns his gaze to his recipient two times of the 4 times he performs the depiction. He does this once at the beginning of the talk and action when he introduces the depiction for wind/force as a lateral sweeping gesture. And does it again at the end of the segment when he turns to Eliza and asks, “Do you have any questions so far?” Eliza shakes her head. Gary’s gaze shifts to Eliza are sandwiched between his gestured actions. The gaze works to highlight the demonstration for Eliza as being part of the explanation.

During Gary's explanation of force, Eliza hands and body remain relatively inactive. For the most part they are either are crossed over her chest or acting as a headrest. Her dominant action is a slight lateral head shifts as she seems to maintain gaze on Gary as he moves across the length of the board (see Figure 8.10).

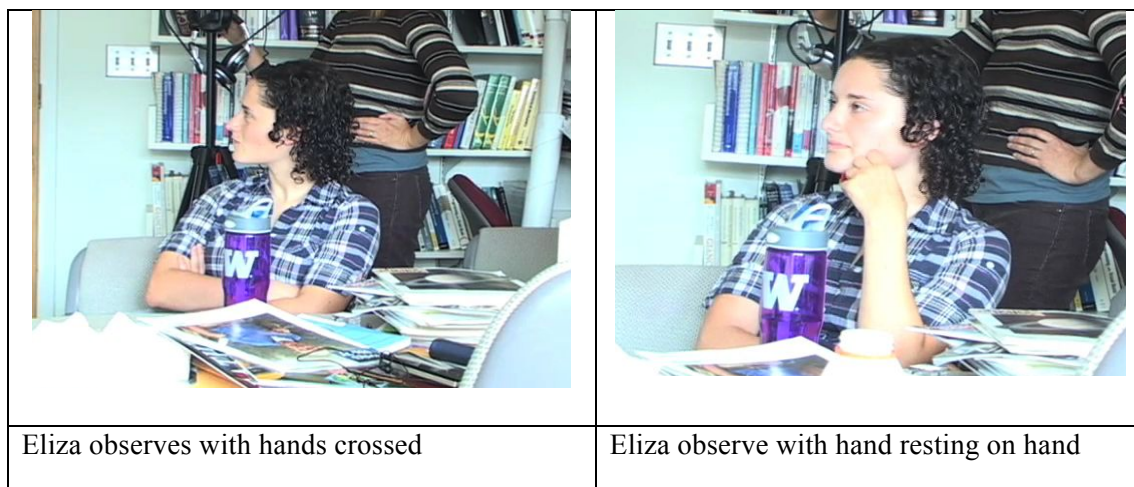


Figure 8.10. Eliza's hands remain inactive throughout explanation

The re-explanation. In the re-explanation Eliza begins by stating, "I really did not understand". When she proceeds to discuss the Higgs Field, she uses the paper provided and draws the sailboats, as did Gary. At one point she says, "I am trying to visualize what was on the board." When she discusses the wind as force, She draws an arrow, as Gary did, to indicate the wind. Her hands, however, do not depict the motion of wind. (I further examined data from camera three that was positioned over the paper for gestural activity to see if any movements could be constructed as depictions of wind/force. The data did not reveal any lateral movements over the paper either with her finger or the pencil when she discussed wind or force).

Through this portion of the explanation, there are no depictive gestures related to the idea of force. Interestingly, however, once I, as researcher, declare the conversation is

complete, Eliza drops the pen, pushes herself away from the desk. As she talks about force her hands begin to enact “force” (see Figure 8.11).

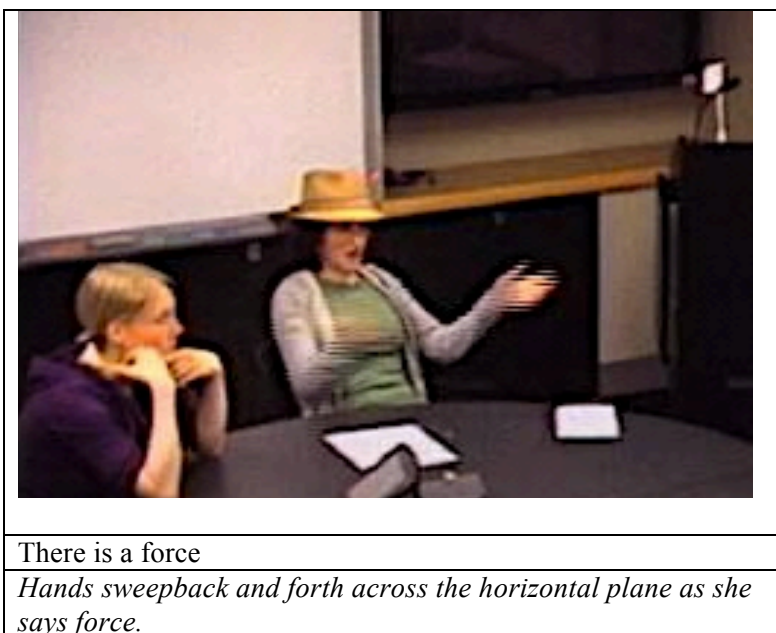


Figure 8.11. Eliza performs depiction in re-explanation for researcher

The gesture is slightly different here in that two hands enact force as they move in opposition to one another. It is the same in that it is a lateral sweeping motion that slides across the horizontal plane repeatedly and it partnered with the word “force”.

Case 1: What has been gained from the analysis. Despite Gary’s building of the concept and his gestural enactment, gestures are not taken up in the explanation. This is possibly the case for many reasons. First, although Gary sufficiently coordinates his gestures with the images and the talk about force, his gestures are competing with the visual images that dominate the board. This is evidenced when Eliza says. I am trying to visualize what was on the board.” Gary’s ephemeral gestures are over shadowed by the stable images on the board. This may be a contributing factor to why gestures are not taken up. But I would like to suggest that the lack of pick up might be due to the lack of interactional possibilities. The lack of interactional possibilities may be due to the

arrangement of the conversation that mimics the classroom. The discussion begins with, “Today we are going to talk about...” an introduction reminiscent of classroom lectures. (In fact, it is not “we” who are talking about the concept, but just Gary). Also much like the classroom, the board dominates the space. Gary fills the board with domain specific inscriptions and formulas, and uses language specific to the discipline, while Eliza sits near a desk and watches. Although Gary takes some opportunity to face his recipient, much of the time during this segment of explanation his back is to her (see Figure 8.12).



Figure 8.12. Explainer’s back is often to recipient in explanation

The context is defined as being like the classroom and roles are defined as teacher in the classroom and student in the classroom - an arrangement and construction of roles that carries with it the expectation of student as listener and teacher as speaker. Even though this is not the classroom, these ingrained conceptions of what it means to be a student are still ratified by the similarities evident in the arrangement. Such conditions, conditions from classroom arrangement and reproduced here in a face-to-face, one-on-one arrangement, suggest reduce the possibilities of interaction thus reducing the explanation to a demonstration rather than a conversation. For instance, when Gary asks

if she has any question after his explanation of force, giving opportunity for interaction exchange, her answer is “no”. But in fact, as revealed in her opening remarks in the re-explanation, (“I did not really understand”) explanatory exchange would have been helpful.

I suggest that these conditions have something to do with the minimal gestural take up we see from Eliza in the re-explanation. The only moment gestural action for depicting is present is at the end of the re-explanation when we close the official discussion and the researcher and participants try to figure out the idea together. This rise in gestural use at this point in time and under these conditions raises questions. Why does the depiction appear when the arrangement changes? I would like to suggest that the reason it appears is related to the same reason it does not appear in the explanation. The learning arrangement has changed to invite possibilities for interaction. Merely stating the explanation is over releases Eliza from having to supply an explanation. And by the researcher stepping in and commenting “that was some complicated stuff he was talking about” (Scopelitis Fieldnotes, 5/21/2009) changes the arrangement to be an interactive conversation for “figuring out” together.

I take a moment to direct the reader back to Example 2 that appears at the beginning of this chapter. Example 2 is Gary second explanation while the explanation with Eliza is his first one. It was during the second explanation in which I introduced the alteration in the interaction by suggesting that Gary treat the second explanation more as a “casual conversation” than a “lesson” (Scopelitis Fieldnotes, 5/28/2009). As a result, the structure changed. Gary, for example, spent less time at the board, walked around the room, and addressed researchers behind the camera. In the second explanation,

represented above, Gary also faces his recipient as he gestures. The recipient, although not producing the gesture in conversation in the explanation session, does carry the gesture over into the re-explanation. This is further evidence that possibilities for interactional arrangement affects the role and use of gestures in explanation and across to re-explanations.

Case 2: The gestured depiction is taken up: A case for establishing interaction in order to further highlight gestured depictions.

Settings.

Explanation. The expert's office

Re-explanation. A small conference room on campus

Concept. Dimensional Geometry

Participants.

Max: Expert - Professor of Mathematics

Calvin: Non-expert. Graduate student in Communications

Gestured depiction. "Hands as dimensional space "

Terry. Confederate recipient of re-explanation

Like the case with Gary, Max builds a conceptual artifact for his recipient. Unlike Case 1, the depiction is taken up in the explanation and re-used in the re-explanation. Case 2 suggests that it is not only enough for gestures that depict conceptual information to be present; but rather it is better for the gestured depictions to be highlighted for and with the recipient through practices that establish an interactional relationship. In this case max highlights the depiction through repetition, size and a consistent coordination with talk as he faces his recipient.

The explanation. Max is mathematician explaining four-dimensional space and spherical geometry. Like Bram, Max builds his concept step-by-step as he presents the main idea and layers on elaborations. Unlike the explanation of polymer solar cell configurations, Max’s explanation uses the black board as well as his hands and body. Max begins his explanation of four-dimensionality by first presenting the full concept of four-dimensionality and then moving to an explicit step-by-step building as he says to his recipient. “What I am going to do is build the dimensions step-by- step”. The board is full of graphs, geometrical shapes and equations. He sweeps across the board coordinating representations to support his explanation Other than graphical representations, Max also creates gestural depictions. The most prevalent gestural depiction throughout this talk is an abstract representation of three-dimensional and four- dimensional space. The gestures alters between being an encompassing form in which is hands look as if they are holding a ball to a circular sweeping action in which his hands trace a large spherical shape (see Figure 8.13).



Figure 8.13. Hands as depiction for the concept of dimensional space

Max’s depiction is a conceptual reference that stands in for the concept of dimensionality. These conceptual gestures fill Max’s explanation. Instances of gestural activity for depicting three-dimensional and four-dimensional space appear a total of 24

times. (Instances are defined by the moment the hands come into the space to the moment where the depiction dissolves. To be defined as an “instance” the actions had to be associated with talk of dimensions).

Following I look at only 6 of the 24 instances. These all appear in less than one minute of talk (see Figure 8.14 and 8.15) giving information in how present these gestures are in his explanation.



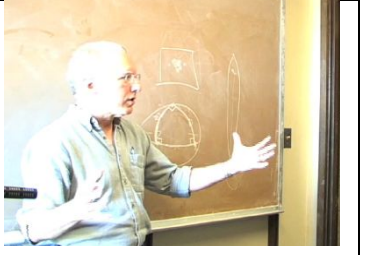
		
<i>Time: 6:54</i> <i>Example 1</i>	<i>Time: 7:14</i> <i>Example 2</i>	<i>Time: 7:18</i> <i>Example 3</i>
I am not saying this is the physical reality and that there is some 4 dimensional space out there	But to model it mathematically...	You imagine something like a 4 dimensional mathematical space, which is nothing but ordered quadruples of numbers.

Figure 8.14. Max performs depiction in explanation (1)

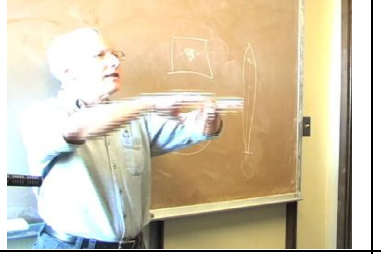
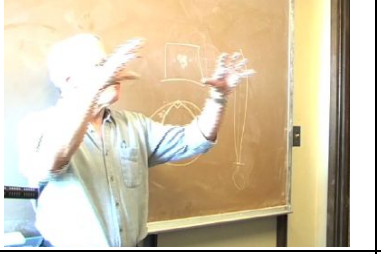
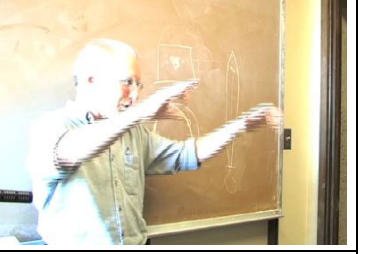
		
<i>Time: 7:24</i> <i>Example 4</i>	<i>Time: 7:36</i> <i>Example 5</i>	<i>Time: 7:42</i> <i>Example 7</i>
In that 4-dimensional mathematical space, you image some hyper-surface.	There is some vast cosmos equation that describes it	It is the 3 dimensional curvy space we are looking for

Figure 8.15. Max performs depiction in explanation (2)

Max’s gestures to depict dimensionality are large and performed in the space between Max and his recipient. He faces Calvin as he performs the gestures and his gaze

is directed to him. (Calvin is seated in a chair 7 feet across from the board.) This is an example of only 6 of the occurrences of this same depiction. All the other 18 recurrences of depictions are also in clean alignment with talk, with Max’s gaze directed to Calvin. The repeated employment of large gestures performed facing the recipient render the depictions as part of the explanation that serve to communicate as well as maintain the recipient’s attention to the explainer.

Evidence that Calvin accepts the gestured depiction as part of the explanation is illustrated when Calvin raises his hands, creates the same gestured depictions as he discusses four- dimensions and three-dimensional space at the end of the explanation conversation (see Figure 8.16).

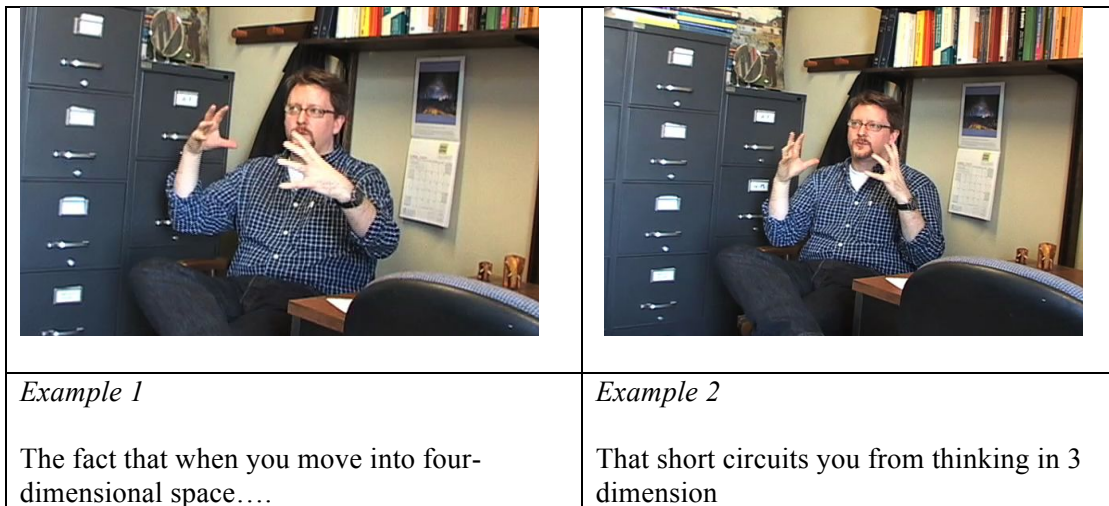


Figure 8.16. Calvin performs depiction in explanation

The gestured depiction for four dimensions appears at the onset of his talk (“The fact that when you move into”) and drops after he utters “dimensional space” 8.15). The gestured depiction appears again when he says, “that short circuits you” In both instances the gestured depiction precedes its reference in talk, suggesting it is invoked to support thinking.

Beyond being a depiction for thinking, it is also used to support the interaction. Studies have shown that idiosyncratic gestures can be taken up by interlocutors to show interactional alignment (Chartrand, & Bargh, 1999). I suggest that Calvin gestural uptake is both a demonstration of interactional alignment and also serves as a mechanism to display understanding as well as a resource to support thinking through enactment. What the gestured depiction does not do in this explanation, as it does in others discussed, is it does not develop a concept jointly over time. It is enrolled as a depiction to represent and reference the entire concept. It is not used to “*work out*” a concept through a process of assembling and thus, perhaps, affecting his level of synthesis of ideas to construct an understanding of the concept.

The re-explanation. When the gestured depiction is carried over into the re-explanation it functions in the same way it did in the explanation. Calvin performs it 17 times with talk that identifies it as a depiction of dimensional space. It first appears when he is explaining what Max talked about. He begins with his hands on the table and says, “He said ‘I’m gonna talk a little about ah (.) Ahm (.) fourth dimension space’.” In the pauses between “ah” and “Ahm” he lifts his hands, close to his own body, gazes to Terry. His hands hold a loose curved shape and he enacts a pulse or beat of his hands when he says “ah” and “ahm” (see Figure 8.17).

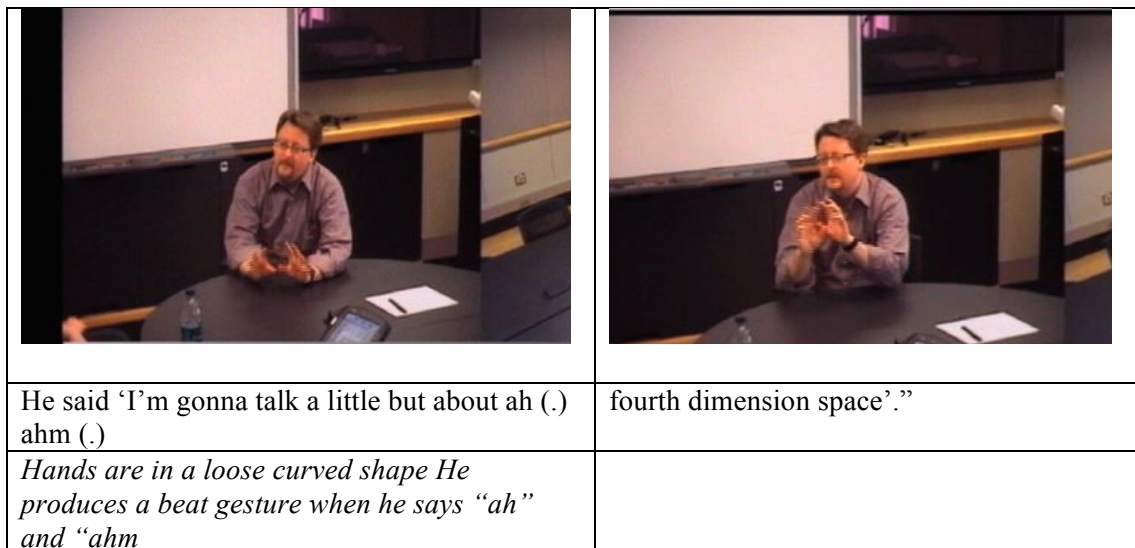


Figure 8.17. Calvin re-creates depiction in re-explanation

By the time he says fourth dimension space, his hands are an abbreviated version of the larger gesture Max performed as he seems to wrap his hands around an imaginary ball. The abbreviated gestured depiction is taken up and used here as a depiction for thinking - a kind of thinking that is used for recalling information in order to transport it. Practices and element that indicate the depiction is for Calvin is the proximity of the gesture to his own body, its abbreviated size, and his own gaze to hands that, by the way, never returns to Terry while the depiction is present, thus never highlighting it as an object for joint attention. The abbreviated gestured depiction seems to work to recall and transport the entire concept of four-dimensional geometry.

Later in the conversation as Calvin attempts to build up the concept of dimensional space his gesture practices change. The depiction becomes larger. It is aligned with talk, coordinated with "three-dimension" and "four-dimensions". The depiction receives an emphatic beat as he presses it closer into the interactional space. As a result, Terry's head drops, perhaps, giving visual attention to his hands (see Figure 8.18).



Figure 8.18. Calvin re-creates depiction in re-explanation

Case 2: What has been gained from the analysis? This case, set against the other cases, suggests that when a gestured depiction is seen it is more likely to be taken up. Max is able to highlight the depiction through repetitions, size, and coordination with referent talk and by gazing face to face with his recipient. But unlike the gestured depiction Bram builds for and with his learners in Study 2, the gestured depiction is not mobilized to change thinking in the explanation or in the re-explanation. As it seems to be both a thinking tool to call up the topic and organize talk in the moment as well as a communicative tool that adds another layer of representation to his talk, that's all it is – another layer of representation. It is never treated discreetly and used to assemble bits and pieces of the concept to achieve a comprehensive articulation of the idea Max communicated. As such, it fails to advance to a tool that allows Calvin to develop new understandings. As a result the depiction only serves to re-tell aspects of the concept rather than re-conceptualize a new idea.

As it is significant and valuable in itself that the gestured depiction, in fact, does appear in the re-explanation, it is further curious as to the role it serves. It is different than, for instance, Raya's use of the depiction to work out ideas through enactment and

scrutiny (Study 3). Raya's gestures developed through her re-explanation and she even comes to create her own to explain the concept. Her understanding also changes from the beginning of the re-explanation to the end. It is even different than Ellie's use of the gestured depiction. Although not achieving a greater understanding of the concept through her re-explanation, the gestured depiction does do the work of allowing her to assess her level of knowledge. Calvin's gestures do not change, nor is there evidence that his understanding changes in the process of re-explanation, either gaining clearer understanding or recognizing gaps in his knowledge. Contrasting Raya's (and Ellie's) gesture use in re-explanation to Calvin's use and in terms of what it buys the learner and how, I suggest interaction between expert and non-expert in explanations matters on whether the gesture depiction carried over to a re-explanation. More interaction, such as using the depiction to ask a question, secures it more so as an entity that becomes part of the explanation. I further suggest that when the gestured depictions are engaged as more than just a restatement, it mobilizes thinking in interaction and takes the learner beyond simply re-telling.

Case 3: When enacted with the expert, gestured depictions mobilize understanding: A case for learner gestures in explanation.

Settings.

Explanation. The small conference room on campus

Re-explanation. A small conference room on campus

Concept. DNA replication

Participants.

Mike. Expert. PhD Candidate in Bio-analytics

Katrina. Non-expert. Graduate student in dance/Professional dancer
choreographer

Conceptual artifact. Hands as DNA

Laura. Confederate recipient of re-explanation

In the following case I show that when a learner enacts the expert's gestured depiction in the stream of the explanation, the gestured depiction is not only enrolled as a viable artifact to recall information, but also mobilized to support further understanding.

The explanation. Mark is discussing DNA replication as background information to discuss the replication of proteins. Mike not only employs gestured depictions in his explanation of DNA replication, the recipient also takes them up and performs variations on his depictions to add and gain clarification.

Example 1. In his first two mentions of DNA, Mark creates a cupped shape with his hands. He uses gaze to his hands and the actions of pushing the gestured depiction into the interactional space and shifting his gaze to his recipient to highlight it as something to attend to (see Figure 8.19).



Figure 8.19. Mark creates gestured depiction in explanation

As Mark continues he shifts his gaze back to his hands before he moves into a different gesture in which he traces out the spiral shape of DNA (see Figure 8.20).

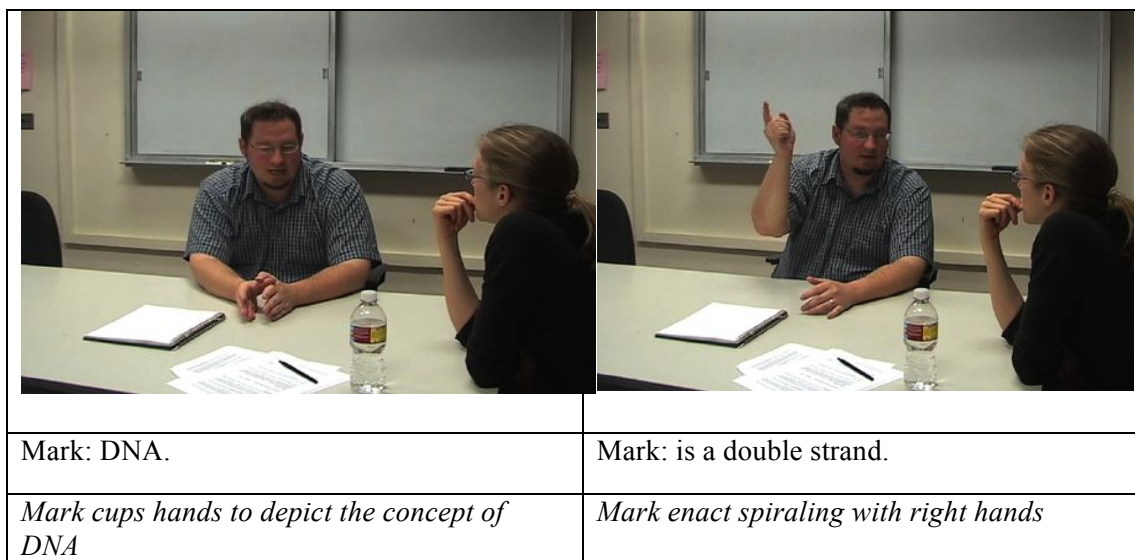


Figure 8.20. Mark adds elaborations to gestured depiction in explanation

As Mark gestures, he adds detail to DNA in talk (“DNA is a double strand”) and gestures. He performs a large spiraling action. His gaze moves to the recipient. This is a composite utterance in which the talk provides information that there are two strands, and the gesture provides information that the strands are in spiral shape.

Gestures are not always taken up in the form in which they were performed. As Katrina takes up the turn offered to her, she picks up the gestural action and confirms her understanding as she performs the variation of the spiral action in her hand. Katrina holds her hand with the thumb and index finger extended creating a space and then flips the shape clockwise as she says “Like a helix”, creating a spiral motion (see Figure 8.21) Re-iterating the specification of the spiral in her hand and her talk gives evidence that she made use of his gesture, for talk alone did not give information about the spiral.

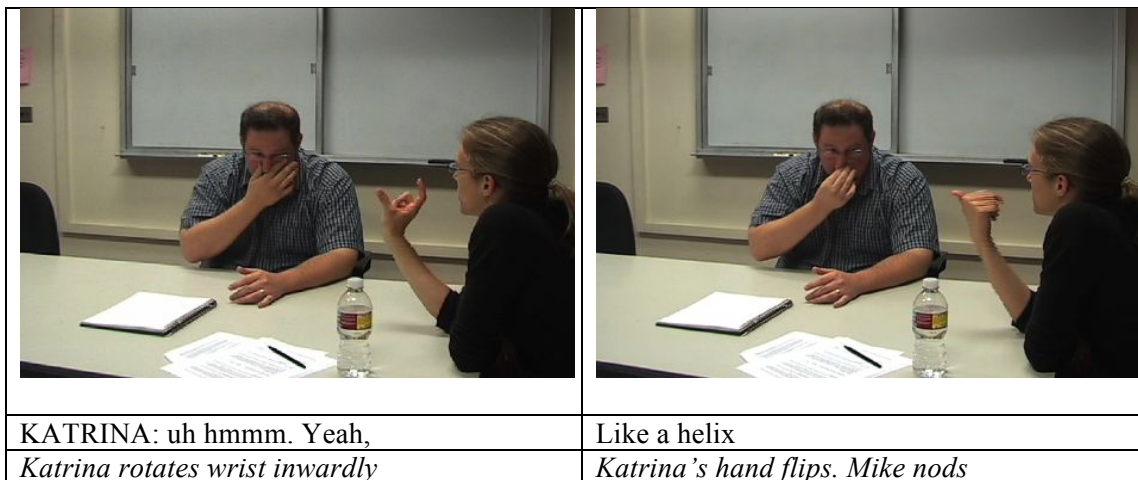


Figure 8.21. Mark adds elaborations to gestured depiction in explanation

Katrina adds onto the concept by adding the association that the DNA is like a helix, translating his spiral gesture into words as she also performs her own variation of it. Here is an example showing that building is a joint process that happens across modalities and between expert and learner. Katrina advances the specification by adding the talk “like a helix”. Katrina also does not simply repeat his gesture but does her own variation of the spiral. To move to perform the concept in her own way suggests a level of understanding that a pure mimicked gesture may not provide. The concept has been translated into her own gestures, as well as into her own words.

Example 2. In another example, Katrina takes up Mark’s gestures to both ground information in her own body and gain clarification. In the pause after “Um” Mark looks to his hands. He spreads his finger as he slides his hand into the interactional space. He continues with “When a fetus’ hand develops”, his hand is open and on the table. When he adds, “it starts out as a big stone”, he lifts his hand off the table, pulls his fingers in to create a fist and adds a beat with this new built depiction as he says “stone”. At the same time Katrina utters an inquisitive “Huh” and remakes the fist gesture in her own hand (see Figure 8.22).


	
MARK: Um (.) When a fetus' hand develops	it starts out as a big [stone]
	KATRINA: [Huh.]
<i>Moves hand from near space into interactional space. Focus goes to hand</i>	<i>Katrina copies fist as stone</i>

Figure 8.22. Katrina copies Mark's depiction in explanation

The gesture depiction, perhaps, serves a similar role to the “marked gestures” both Raya and Ellie performed to ground information. The depiction is near to her own body, is brief, and happens in the absence of speech.

Mark continues using the hands as a depiction for illustrating the explanation. Mark slides his right hand down the fingers of the left hand as he says, “to create the fingers” and space holds the depiction as talk continues. His gaze is directed to Katrina (see Figure 8.23).


	
MARK: and cells die so to create the fingers	So the ones that don't die (.) create the fingers.
<i>Mark slides right hand down the form of the left hand enacting how fingers get created.</i>	<i>Mike touches his fingers</i>

Figure 8.23. Mark creates depiction in explanation

When his hands come to rest, indicating the explanation is complete and the turn is now open for Katrina to take, Katrina picks up the gestured depiction and re-phrases the information related to the fist gesture into her own words.

It is a depiction to communicate her thinking in order to ground it. The use of the word “So” at the start of “So instead of the fingers growing out, this comes in?” indicates the talk and gestures are a composite summation of what Mark relayed. This, in turn gives Mark the opportunity to move forward from this metaphor to explain that the DNA the hands are made of consists of a certain order of amino acids and that a chain of amino acids makes up a protein (see Figure 8.24)



Figure 8.24. Katrina re-creates depiction in explanation

The re-explanation. In the re-explanation Katrina transports and assembles parts of the explanation in both talk and gestures and synthesizes them into a concise explanation.

Example 1. Katrina transports the metaphor of the body growing. As she begins the discussion she first looks to her hands, creating the similar extended, open palmed shape performed in the discussion that led to an explanation of the relationship between DNA, amino acids, and the making of proteins (see Figure 8.25).



Figure 8.25. Katrina creates depiction in re-explanation

Her hands are consulted as information holders for her to transport information. She seems to transport the information that was expressed in the talk that immediately followed the gestures she and Mark performed that represent a fetus's hands growing. She looks to her hands and says, "you have proteins that are part of your DNA." The hands here are not working to represent the concept, but rather trigger the talk that followed the depiction highlighting hands.

Example 2. The prior talk and gesture seems to activate an assembly of information with in the same moment it is expressed to her hearer. She begins with, "He sort of rewind....". In the pause she creates a "cupping" gesture, much like Mark's. Her gaze goes to her hands (see Figure 8.26). The talk partnered with the gaze to her hands suggests that the gestured depiction is again transporting information. A quick process of assembly occurs that allows her to now press the depiction into the communicative space to express the idea of the DNA being a double helix. The performance of the double helix is a counter clockwise turning and spreading of two hands (see Figure 8.26). This is not a replica of Mark's gesture nor of her own from the explanation. It is rather a composite of both their gestures and their talk.



	
KATRINA: He sort of rewind to DNA. DNA	which is this beautiful double helix.
<i>Gesture is in near her own space</i>	<i>Gesture gets pressed into interactional space</i>

Figure 8.26. Katrina creates depiction in re-explanation

Here is a clear example that the concept was jointly built in the explanation. The blended variation still very confidently holds the concept but in a different morphology. This is interesting and reminds me of gestures Raya creates in the re-explanation that are of the same nature. For instance, Bram never lifts his elbow and slides his hand down to represent the absorption of sun energy, as Raya does toward the end of her explanation. This is her own creation that retains the same concept and develops off his gestures. This raises the question of how information is assembled. Perhaps the performance of the gestures with the explainer and the re-creation of composite gestures in the re-explanation represent a synthesis of understanding for the learner. It is similar to transitioning spoken or written information into our own words. Information that eventually is strung together to create a whole, as the next talk and action demonstrate, helps mobilize and transform learning.

Katrina moves on from the presentation of DNA and connects information she gained from the take up of the gesture in example 1. As she talks the “hand gesture” appears again, and again in coordination with talk, this time more elaborate, about proteins. Katrina touches her fingers of her hands briefly and says, “ within that code

every part of the body has a different order of amino acids (see Figure 8.27). She goes on to recreate the cupping gesture with a slight rotation that has come to depict DNA as she utters, “And those part of the DNA, those little parts that make up the DNA”. She finally assembles all the parts collected in the disparate gestures in her next unit of talk and action. Her index finger and thumb of both hands pull together and she says, “and those little parts that make up the amino acids are equal little proteins” (see Figure 8.27).

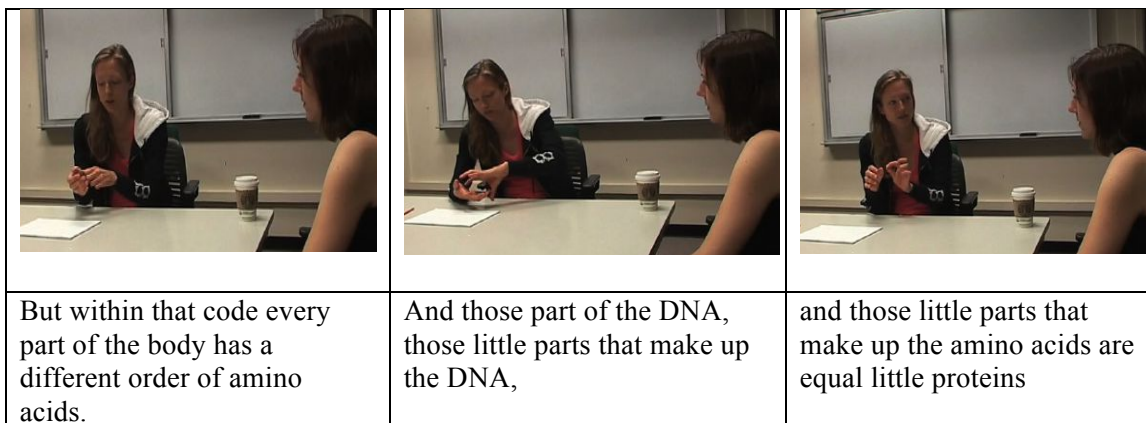


Figure 8.27. Katrina creates depiction in re-explanation

The entire re-explanation that emerges out of the talk of DNA and includes the understanding of the relationship of DNA and amino acids follows below (see Figure 8.28 and 8.29). The structure of Katrina’s re-explanation resembles the structures created when experts share known concepts. The re-explanation has a beginning in which the concept is introduced, a middle in which elaboration are sequentially strung together, and a conclusion that makes articulate a point. There are also gestural actions that represent that she is thinking through the ideas at the exact moment she is communicating them. For instance, she gazes to her hands in the moment of connecting the idea that DNA is made up of a combination of amino acids. Her gesture shows she understands it to be a string as she laterally slides one hand away from the other.) Her talk and action show she knows (1) DNA has a human code, (2) the body creates an order of amino

acids, (3) amino acids are part of DNA, and (4) parts (sequences in triplets) of amino acids make up a protein. When she reaches this conclusion her gaze goes to Laura.




		
DNA, which is beautifully double Helix pattern	is built out of a combination of what are called amino acids.	And all DNA, there is a code for all human DNA.

Figure 8.28. Katrina creates depiction in re-explanation




		
But within that code every part of the body has a different order of amino acids.	And those parts of the DNA, those little parts that make up the DNA,	and those little parts that make up the amino acids make up little proteins

Figure 8.29. Katrina creates depiction in re-explanation

This re-explanation is an example of the hybrid space in which gestures are used to both think through ideas and communicate ideas in the process of interaction.

Case 3: What has been gained from the analysis? This case shows that is when gestures are enacted with the expert in the explanation, they hold the possibility of being more than just enrolled, but also mobilized to pass understanding along further in both the explanation as well as in the re-explanation. That is, when the gestured depictions are used to work through understanding under the watchful eye of the expert then both the

explanation and re-explanation events becomes a site for the ongoing development of understanding.

Katrina's ability to create variations on the gestures in the explanation suggest that the information Mark brought forth in gestures was not only taken up in Katrina's body, but also able to undergo a level of transformation in the process of enacting the gestures in the explanation. Thus beginning the development of understanding at the very moment of explanation. I suggest that this such experience of the gestured depiction in the explanation as tool a to undergo understanding is what lends to her capacity to immediately assemble information at the same time she transports it in the re-explanation. There is no lag time between recalling information and the start of synthesizing it in the re-explanation because she has already under-gone some of it in the explanation. Katrina's final animated explanation is a clear synthesis of the complex concepts that reflects an incorporated understanding as gesture and talk become her own.

This case supports the theory that how gesture depictions are employed in explanation support how they are mobilized in re-explanation to advance understanding in the process of articulation. Katrina understanding rapidly developed from the beginning of the re-explanation to the end of it. This is not only clear in her change of talk and gesture but further supported by her own comments. As I was putting away the cameras, I complemented Katrina on her clear re-explanation. "You sounded like a scientist?". I said. Her response was I guess I did ok but I certainly did not think I could do it when I first opened my mouth" (Scopelitis, Field notes, 8/15/2009). This comment suggests that in the process of re-articulation, her understanding evolved. The data show that the evolution was in part due to the information the hands held.

Discussion and Implications: Gestured Depictions As Interaction For Learning

Study 4 offers further confirmation of evidence first emerging from the prior three studies. Analysis from the cases here continues to show that effective building of gestured depiction is a careful, strategic, interactional achievement that includes a step-by-step crafting of a gestured depiction for and with the recipient. It further corroborates the assertion that if non-experts treat the depiction as a significant part of the explanation and understanding of the concept they will likely carry it with them over to a re-explanation. The powerful implication is that the body can be fluidly drafted into service in teaching and learning interactions and can serve as a critical and lasting resource for developing understanding, communicating meaning, and executing interactions. What is of critical relevance here is that the extent of this achievement appears to be dependent on certain contingencies in the interactions and how the gestured in engaged by all participants.

It is a significant finding in itself that in cases where gestures were performed that they travel across time with the learner. This gives evidence that learners value more modalities in teaching and learning than just talk. It further reveals that gestures are part of the medium in which understanding is being worked out, negotiated, constructed and constituted. What the data also reveal is the experience of the explanation determines the use of gestures as resources for the learner. That is not to say ALL gestures are valuable resources for learning overtime. But if certain gestures that depict information provide another level for communicating information and “thinking through” information, as the data have shown, then understanding how to use the gestures both as an explainer as well

as a learner seems critical in order to fully gain the affordances that some gestures can offer in the teaching of complex scientific concepts.

CHAPTER 9

BRINGING IT ALL TOGETHER

Project Summary

When I explained to my son Savas that I was studying how people use their bodies when we teach and learn, he responded confidently with “Well, yeah!”, indicating this was a given. He reminded me how I taught him what a peninsula was. “Mom”, he began, “Remember helping me with my homework? You told me to imagine the carpet was water. And then you went like this.” Savas crawled to the floor and curled himself up into a tight ball. “And then you said, ‘Imagine I’m a landmass.’” He paused for a moment, lifted his head out of his balled-up shape to look at me as he said, “Right?” I nodded as he added “And then this would be a peninsula.” He extended both arms out in front of him, pressed them tightly together from the elbows to his fingertips. “So, see my arms? They are surrounded by water.” He used his head to point to the space around his arms as he defined it as water. “That’s what a peninsula is, right?” I smiled to see my son carry gestures over from an explanation that occurred almost a year ago. Savas continued to adjust his body into different positions in the absence of talk. He settled on a “C” shape on the floor where his head curved to reach towards his toes. He pointed to the space in front of him. “Mom?”, he asked. “Would this area be a gulf?” I smiled again to see my son use his body to explore new knowledge.

This interlude with Savas illustrated that gestures and bodily actions created in interactions to explain concepts matter to a learner so much so that they can be recalled a year later to demonstrate and expand knowledge. After my extensive investigation into the role of the body in teaching and learning, it is of no question to me that one reason

Savas's learning persisted is because of the engagement of our body's in a prior interactive explanation where we both used embodied actions together to communicate and think through ideas that concluded in the accomplishment of joint understanding.

This dissertation was an empirical investigation to explore what Savas already knew – “gesturing is just what we do” when we are explaining and learning with other people. This project was motivated by an interest to explore how the body participates in interactive teaching and learning for the explanation and understanding of STEM concepts. The driving question that motivated this investigation was how do experts use their hands and body in face-to-face interactions to explain complex STEM concepts to non-experts? In Phase One of this project, I collected videotaped data of experts from STEM fields (professors, researchers, and graduate students) explaining a concept of their choice to myself and another researcher, both of us non-experts in STEM fields. Preliminary analysis revealed that people do use their hands and bodies in creative and strategic ways to explain concepts. Preliminary analysis also suggested that this was a joint construction between explainer and recipient.

From this preliminary analysis emerged a new question about the reciprocity of gestures. The second question addressed in this project was; Do gestured depictions used in interactive explanations travel with the learner across time? With the emergence of a new question about recipients' extended use of the gestured depictions, and with the desire to have a less contrived environment, I embarked on Phase Two of the data collection. First, I replaced myself as the non-expert with participants recruited from non-STEM fields. Next, to attend to the question of reciprocity, I added a second conversation in which the non-experts re-explained the concept two days later to a confederate (the

confederate was from the research group of which I was a part). In all cases, experts were asked to explain a concept of their choice. Non-experts were asked to try and understand enough so they can re-explain ideas to another person. In all cases, all participants were not aware of the focus of the study and were not asked to gesture. Therefore, all gesturing appearing throughout the data is naturally occurring.

Making sense of the data. I first analyzed the entire data set made up of 32 hours of videotaped conversation looking for instances in which experts used gestures as a medium for explanation. In cases where a re-explanation followed an explanation, I looked for the take up of gestures used to express the concept in the explanation. Take up was defined by any or all of the following criteria: (1) A recipient's direct remake of the gesture in form or action, (2) a recipient's adaptation of the gesture in form or action, and (3) a recipient re-use of the gesture in either its exact form or in an adapted form as it is partnered with the talk in which it was first introduced.

I framed this project with the epistemological view that learning happens in the activity of being in the world and that knowledge is constructed not only in the context of our minds, but also always in partnership with our actions and experiences in and with our world. I hold the view that knowledge cannot be divorced from our interactions and relationships with the people, things, contexts, and histories that make up the dynamic, moving networks of our lives. Included in this assemblage is the human body. My investigation has been framed around the concept of the body as (1) capable of construing concepts, (2) as one of the prominent mediums and modes used in a distributed system where knowledge is accumulated, constructed, and constituted across activity and interaction, and (3) that the body and the hands, do not serve only one functional role, but

rather slide gracefully across functions. These functions include (1) the act of communicating information (I have referred to these such gestures created by the maker as gestures “for you”), (2) the process of thinking through information (I have referred to these such gestures created by the maker as gestures “for me”), (3) the work of steering the interaction toward a shared goal (I have referred to these such gestures created in interaction as gestures “for us”). Gestural activity does not simply serve one of these functions in a single moment, but rather moves across functions moment-to-moment based on the multiple contingencies of the interaction.

Shaped by such perspectives, I defined interactions where concepts were explained and developed across people and the body, as well as other available resources, as “interactive explanations”. The idea of “interactive explanations” develops out of the perspective of disciplined perception (Stevens and Hall, 1998, Stevens, 1999). Disciplined perception is a term used that refers to the multimodal activity participants employ in interaction when the more knowledgeable person is training a less knowledgeable person how to “see” in order to participate in a discipline. I frame explanations as a genre of this activity. I engaged the term “interactive explanations” to express the position that the explanation of concepts can be a dynamic exchange between people, the context, and the resources available and activated in a learning arrangement. The term “interactive” refers to the back and forth exchange across people, things, and action that allows for the planning, crafting, and building of explanation and learning. As each turn in action and talk is based on and updated from prior turns and actions involving all participants that include the body, explanation and re-explanation become a performative, improvisational, exchange that rolls toward the joint achievement of

conceptual understanding when one person who knows more about something explains it to a person who knows less. The data confirm that in the process of interactive explanations and re-explanations it is more than just talk that participates in the achievement of joint understanding. The body, too, is an equal player that supports communication, thinking, and interaction to achieve a change in learning.

I approached this data from the methodology of microanalysis of videotaped interaction. This process of analysis allowed for the close investigation of moment-to-moment, turn-by-turn, interactional exchanges and gave me detailed information about what was happening in a particular instance (e.g. Derry et al., 2012; Erikson, 1995; Garfinkle, 1967; Goodwin, 1993; Jordon & Henderson 1995; Schegloff, 1987; Stevens, 1999, 2011; Stevens & Hall, 1998; Streeck & Mehus, 2004). I used videotaped recordings to examine the micro-behaviors of participants in face-to-face dyadic and triadic explanation arrangements as a means to better analyze ways in which various resources such as the body are drafted into service as functional modalities for teaching and learning (Stevens & Hall 1998; Streeck & Kallmeyer, 2001).

Findings presented in this project developed out of a preliminary analysis of all cases within the data corpus. Borrowing from grounded theory (Straus & Corbin, 2002), I observed what people did across situations and pulled out emerging themes. From this I developed a general theory about the role of gestures and the body in teaching and learning. That is, that people use their hands and bodies strategically together to achieve joint understanding. I then extracted data from the larger corpus and analyzed data clips more closely, looking for the themes as well as allowing new themes to emerge and

general theory to evolve. The data presented in this dissertation have provided the opportunity to best answer the questions posed.

To discuss the first question - How are gestured depictions used in interactive explanations constructed and accepted as viable resources for explanation, and, once established, how are gestured depictions used and adapted by both the maker and the recipient to achieve explanation and understanding? - I presented Study 1. Study 1 is an analysis of segments from three interactions in which experts (two professors and one graduate student) explained concepts in microbiology, mathematics, and animal biology in one-on-one conversations with a non-expert. From the analysis emerged categories of phenomena that included (1) experts build gestured depictions step-by-step for their recipients, (2) that the use of the gestured depiction develops out of the perceived sense of a recipient's need to understand the concept. (3) Recipients take-up the expert's gestured depictions to extend understanding, and both the explainer and the recipients use gestures to correct the learner's misunderstanding, (4) Gestured depictions are used by all participants to think through concepts together as they are passed back and forth between participants and treated as cognitive and communicative resources in the pursuit of building understanding, and (5) gestured depictions are used by both the explainer and the recipient to steer the interaction toward the shared goal of achieving conceptual understanding.

To give further credence to phenomena emerging from three short instances, in Chapter 6 I presented Study 2. In Study 2 I analyzed an expanded explanation lasting 40 minutes in which Bram, an expert in chemistry, explained the fabrication of polymer solar cells to two non-experts, Raya and Ellie. This data showed that categories of

phenomena uncovered in the prior analysis of short segments of experts explaining complex STEM concepts to non-experts also emerged in a single extended explanation. This is a meaningful finding because it shows that the gestural practices used by experts to explain concepts to non-experts in the three short segments first analyzed are not just single instances of these phenomena, but also are patterns that are part of a coherent gestural rich extended explanation. In addition, the analysis uncovered new phenomena that included (1) that learners used gestured depiction as both visual and visceral perceptual resources to support understanding. That is, the gestured depictions can slide between being representations that are made on the body and primarily engaged as graphical resources to be viewed to also serving as haptic experiences that are primarily incorporated in the felt body. (2) Gestured depictions accumulated meaning for the learner throughout the explanation, and (3) gestured depictions used to explain a concept became a shared association used by both explainer and recipients to extend questions and expand learning in the course of the explanation.

In Chapter 7 I presented Study 3. I addressed the question - Do gestured depictions used in interactive explanations travel with the learner across time? I turned to the re-explanations of those recipients participating in Study 2. I presented analysis that illustrated (1) that recipients carried gestured depictions built in explanation over to their own re-explanations and (2) the distribution of the functional uses of the gestured depiction changed as the learner moved to explainer charged with the task of figuring out AND communicating a newly learned concept. That is, the analysis revealed that the gestured depiction served more time as a tool for thinking (gestures “for me”) as opposed to the expert’s use of the gestures as depictions for communicating (depictions “for

you”). This is meaningful in that it shows that the function of the same gestured depiction in form is shaped and adapted to serve the needs of the participants. Finally, the analysis provided an emerging theory that the way recipients used gestures in the re-explanation to support their developing understanding may depend on how they were experienced in the explanation event.

In Chapter 8 I presented Study 4. I applied all categories of phenomena that were distilled from prior analysis to varied cases from across the data corpus in which experts explained concepts of their choosing to non-experts and those non-experts re-explained to another non-expert to not only give opportunity to further establish the generality of these phenomena, but to also investigate why and when these phenomena occur. I presented data from seven diverse cases in which the level of gestural activity across the explanation and re-explanation differed. This allowed for a level of comparison to provide insight about the relationship to how gestures are used in the explanation to how they are carried over into re-explanation, thus revealing more about how people think and learn with the hands and bodies in face-to-face learning interactions in and across events. Findings suggest that there are criteria for gestures used in the explanation that make them successful resources for the learner in re-explanation. Also revealed across this comparative analysis is that gestured depictions must be more than just present to earn their value as a effective tools for teaching and learning. They need to be accepted as part of the explanation and used in the process of building joint understanding. In the explanation gestured depictions must be highlighted for the recipient. This requires an awareness of a recipient’s attentional orientation and a strategic use of talk and action to make and maintain the depiction as a valuable source for the interactive explanation.

Gestured depictions must also be made of use by both the explainer and the recipient during initial explanations. This finding suggests that gestured depictions are of more use as a durable learning resource across time when they are engaged by both the expert and the learner to negotiate meaning together. Further, more use of the gestured depiction in interactive explanations gives it more value for further learning. This finding suggests that the level of interactional exchange across the participants along with the use of the gestured depiction in the explanation event influences when and how gestures are re-used in the re-explanation to expand learning. Finally, gestured depictions can be a resource to expand learning. That is, when gestured depictions are enrolled by the learner to not simply transport information but to explore it in the process of assembling information, thinking is mobilized and learning is achieved.

Collectively findings determine that gestured depictions do, in fact, do quite a bit for teaching and learning. This adds to previous research on gestures as it situates the investigation of gestures in the field of educational research and gives deeper analysis into *how* gestures participate in teaching and learning. Such findings move us one step closer to understanding the body as one of the many participating modalities for teaching and learning and give us more insight into what makes for effective instruction.

Implications for Teaching and Learning: Constructing Gestured Depictions

To Be More Than Just Present

Following I draw from the previous analysis chapters to discuss implications and limitations for this dissertation. The implications are built on the characterization of gestures as useful resources for teaching and learning in face-to-face interactions for

explanation and re-explanation. It is of value to learn that gestured depictions can be co-constructed and recognized by all participants and used to jointly achieve explanation and learning. It is a significant finding in itself that when gestured depictions are performed in the explanation that they travel across time with the learner. This is evidence that teachers and learners recognize the body and gestures are part of the medium in which understanding is being worked out, negotiated, constructed, and constituted in interactions. It is also important to come to know that gestured depictions serve multiple functions in teaching and learning interactions. Employing gestured depictions in teaching and learning arrangements as interactive and inter-dependent resources that collectively serve to buttress thinking, support communication, and shape interaction is an improvement on the dominant cognitive view in educational research, and gives due attention to the complexities of affordances the hands and body hold.

The broad implication for teaching and learning deemed from this research is that gestured depictions must be more than just present if they are to assume their potential for teaching and learning in interactions. The data has shown that gestures are not simply objects, but also forms of actions, that when engaged strategically contribute to the achievement of joint understanding. As the data illustrate this as so, explainers must then take care to sequentially build the gestured depictions for the recipient. This includes not only scaffolding the building process by adding elaborations step-by-step. It also includes that the explainer adopts the strategy of embodied recipient design and intently assumes the recipient's perceptual stance on the gestured depictions the maker creates. The explainer needs to organize the interaction so the recipients take up the depiction in their own hands. This, in turn, gives the learner the opportunity to negotiate the information

performed in the hands under the watchful eye of the expert. Now in the recipient's hands, the use of the gestured depiction evolves in the interactive explanation. It not only becomes an opportunity for the learner to think through information and record information in the body, it also becomes an action for formative assessment.

As the gestured depiction moves across time and across participants it also moves across functional roles. Understanding gestures as communicative (maker's gestures are "for you"), cognitive (maker's gestures are "for me"), interactional (gestures work "for us") gives opportunity for gaining full use of the affordances of gestures situated in interaction to support the sharing of information, the synthesizing of new knowledge, and the shaping of interactional possibilities. These implications will be discussed in more detail to follow.

Constructing gestured depictions as active participants for teaching and learning. Research has suggested that the more teachers gesture, the better students learn (Alibali & Nathan 2006, 2007; Goldin-Meadow, Kim, & Singer, 1999). But there is more to this story. An explainer's gestured depictions need to be more than present entities in an interaction if they are to serve teaching and learning. The gestured depictions need to be strategically and creatively built for and with the recipient and used as joint resources by both the expert and the learner.

It is not simply that more gestures equal better teaching. What seems to influence the gestures as support for learning is how they are constructed and managed *for* and *with* the recipient in interaction. Successful explainers have practices for building, highlighting, and guiding recipient's perception of gestures that make them of use to the recipient. The explainer must not just bring the gestured depiction into the conversation.

He needs to highlight it and direct the recipient's attention to it through an orchestration of action, gaze, and talk. Once accepted by the recipient, explainers move forward to add elaboration of the concept onto the gestured depiction. This process of adding details is a sequentially, scaffolded, step-by step construction in which the explainer keeps track of the recipient's attentional orientation to the depicting hands, and reining attention back if it drifts. This is a complex process that reveals that an explainer needs to do more than use his hands when teaching. He needs to craft the interaction to achieve that the movement of the hands holds meaning for his recipient. When this is successfully performed, then the gestured depiction is recognized and thus used by the recipient. It becomes a shared resource employed and developed for the advancement of the teaching and learning activity. As such, the gestured depiction is mobilized in the process of interaction to be an active participant for teaching and learning.

Recipients engage the gestured depiction in their own hands. The data suggest that the extent of the recipient's experience with the gestured depiction in the explanation interaction affects the level of its function as a resource to extend thinking when taken over into the re-explanation. The implication is when experts and non-experts both interact with the gestured depiction it accumulates more power to serve later and deeper learning.

As all recipients in the cases presented did carry the gestured depiction over into the re-explanation, the extent of their uptake and functional use, and thus functional value, varied. Gesture use ranged from a single take up of the gesture (as was the case with Eliza) to a rich use of gestures, that included direct take up, variations of gestured depiction, to the creation of unique depictions conveying concepts in new ways. This

latter use was particularly evident in the cases of Raya and Katrina's re-explanation. Data showed that gestures can be taken up and used as active resources to develop and mobilize understanding in the process of re-explaining to another. Comparison across cases shows that gestured depictions taken up by the learner hold the potential to not only function as expressions to reveal a learner's thinking (e.g. Goldin-Meadow, McNeill), nor only serve as memory banks to transport information (Hutchins, 1995). When gestured depictions are taken up by the recipients they also do more than just simply re-present the concept, as was the case as Calvin carried over the depiction of dimensionality. Gestured depictions taken up and carried to the re-explanation can also serve to develop a learner's thinking. They can be used to work out understanding and constitute conceptual development. However, as the data suggest, for gestures to reach this level of potential as thinking tools in the re-explanation they need to be experienced as possible thinking tools in the explanation. That is, gestures in the explanation need to be more than just built for the recipient. They even need to be more than just copied. They need to be in the hands of the learner as resources to be manipulated. The implication is that that interactional activity in the explanation event between the people as well as the depiction, invites a high level of meaningful use of gestures in the later re-explanation event.

Gesturing “for you”, “for me”, “for us”. The data further reveals that examining gestures for the function they serve for the participants in the interaction, gives insight into the pliable nature of gestures and how participants strategically make use of the functional flexibility to cross and blend affordances to achieve the end goal of joint understanding together. Understanding gestures as acts for communicating (maker's gestures are “for you”), acts for thinking (maker's gestures are “for me”), and

interactional acts (gestures work “for us”), and seeing that these functions change from moment-to-moment to serve the goal of explanation and understanding gives insight into how people make use of gestures in more complex and layered ways than previous research suggests. The implication of this study for further research on the role of gestures in teaching and learning show that by taking an approach to studying gestures for teaching and learning that recognizes functional roles as communicative tools, thinking resources and interaction directors better reveals the way in which people routinely accomplish teaching and learning.

The hands and body do not take on one of the roles but rather slide across these functional roles to achieve the shared goal of explanation and learning. When an explainer gestures, the gestures are not only used to communicate. They also are engaged by the explainer to shape and direct the interaction and the attentional orientation of his recipients. Bram does this, for instance, when he lifts the gestured depiction into the interactional space, gazes to his hands, then to his recipients, and then presses the depiction further towards his recipients as he says, “Like that”. When in the process of communicating, one functional role cannot exist without the other if the goal is to achieve explanation. Without using the depiction to gain attentional orientation, the information in the hands would have been lost for the recipient. Thus the action is not achieved if one function is left out. This demonstrates the integral relationship between the functional roles a single depiction can assume in a single instance.

The same inter-dependent relationship between functions is also true when the recipient accepts the gestured depiction and remakes it in her own hands to ask a question or gain confirmation. The gesture becomes a depiction that supports the recipient’s

thinking by communicating how she is thinking to a more knowledgeable other, able to offer information. It becomes part of the hybrid space in teaching and learning when functions overlap. Here it is a depiction for communicating thinking, but it is also more. The gesture, in turn, acts as a bid for the explainer's next turn, which is asking for the assessment and guiding of her thinking to achieve understanding. It also becomes a tool for interaction by shaping the next turn. Here, one gesture at one time is supporting thinking, communicating to another, and setting up the next turn in the interaction. Again the action does not progress forward if only one of these functions was in use.

Similarly so, the role of gestures in the re-explanation as a tool for thinking as a way to transport information and assemble bits and pieces happens while also communicating to a recipient. The learner assesses her knowledge when she communicates information through the hands and then moves back into using her hands as a tool to think through information. The back and forth exchange between using the hands as resources "for you" as communication is performed and as resources "for me" as thinking ensues, shows that the interwoven relation between both functions unfolds toward understanding. The interaction between the gesture depiction as an act of thinking and then communicating becomes a cyclical and dynamic activity as it mobilizes thinking in the individual and in the world to move understanding forward.

The various functions of the hands and body, then, slip and slide across each other; they partner up with one another; they complement each other. And the functions they assume at any given moment are determined and negotiated through a complex interactive exchange between explainer and recipient as need and aims are re-organized across the moments. For an educational researcher to adopt the perspective as gestures as

simultaneously and interchangeably as communicative, cognitive, and interactive resources is an improvement on the dominant cognitive perspective that exists in research about gestures and learning. For educational researchers to take the view, as presented in this dissertation, that gestures assume multiple functional roles that work with and for one another to drive the action to its achievement will offer the opportunity to examine gestures as the complex changing mediums they are in the activity of teaching and learning, thus earning the field of educational research a better understanding of how teaching and learning happens.

Interaction matters. If we treat the participants (and all they bring with them) and the gestured depictions as multi-functional resources present in the teaching and learning arrangement, then it is the interaction that animates and enlivens them. For without the possibility for interaction, the resources remain relatively inert. In short, for gestured depictions to be of use to the participants, interaction matters!

The data show that the more interaction with the participant and with the gesture in the explanation results in more expansive use of the gesture in the re-explanation that adds to understanding. *A little* interaction buys a *little* bit of something. For instance, as the data shows, the repetition of a gesture when facing the recipient makes it possible it will be carried over into the re-explanation even at least once and even if it is just an animation to their talk (as with Sansa in Chapter 8). This suggests the importance of the simple idea of being face-to-face.

A little more interaction buys even more. Actual take up of the gestured depiction by the recipient in the explanation makes it even more likely it will appear in the re-explanation and be used as either or both a resource to communicate the concept and/or a

resource to transport aspects of the concept (illustrated in the cases of Calvin, Ellie, Samantha's re-explanations). This highlights the importance of embodied action. Just making it in one's own hands gives more than just seeing it in the expert's hands. And even more interaction earns additional benefits of gestures in the re-explanation. If the gestured depiction in the explanation event is passed back and forth between explainer and recipient as a resource to think through concepts together, the analysis showed it will not only appear in the re-explanation event to communicate the concept it will be used and expanded to extend understanding. It also may very well undergo a creative variation, as it does with both Raya and Katrina. Such creative adaptations suggest the concept has been absorbed by the learner and can re-emerge in the learner's hands as a gesture belonging to their own understanding rather than belonging to the expert's explanation. When the same concept is shared using different depictions, this demonstrates a change in understanding.

Making full use of the gestured depiction to communicate information, negotiate, new understanding, and ultimately synthesize new knowledge allows the learner to circle back and communicate understanding in her own words AND gesture. When information turns into knowledge belonging to the learner, expressed in new ways by the learner, it marks a change in understanding. Gestures used as resources of negotiating information can participate in this change of understanding, as the data reveal. As a moving toward a change in understanding is the trajectory of learning for which we aim, gestured depictions that hold information become a vital resource to achieve this when they are constructed and treated as part of the process of teaching and learning

This process begins in the explanation. Both Katrina and Raya picked up the explainer's gestures to ask questions and gain clarification. Both learners copied the explainers' gestures. And, both learners created versions of their own gestures that related concepts in their own way. Both learners also used the depiction as a manipulable tool to figure out thinking in the presence of the expert, expecting and accepting expert's clarification and re-directions. Both learners displayed a broad perceptual use of the gestured depictions. Both Raya and Katrina very often engaged their own hands as a visual, graphical display of the concept, as well as a felt and enacted experience. Such diverse use of the gesture in the explanation gives it the opportunity to be of use to support thinking for re-explanation when the expert is no longer there.

When gestures are engaged interactively in this manner, the expert's explanation is not just an activity for communicating a concept. It becomes an opportunity to practice thinking with the hands in the way the experts expressed with their own hands. It becomes a rehearsal session for the learner with the expert to practice how to think about the concept across such resources as the hands and the body. It becomes an embodied activity for disciplining perception in the process of interactive explanation.

Taking Practices for Making Use of Gestured Depictions in Face-to-face Interaction into the Classroom. Certainly, by the very nature of the classroom arrangement, the available uses and functions of gestures are different compared to those present in face-to-face, proximal, dyadic and triadic arrangements. But surely some of the practices identified in successfully building and engaging the gestured depiction in face-to-face explanations can be effectively performed within current arrangements for classroom

learning. It may not be possible for teachers to have their gestures respond to each and every learner's displayed understanding, but it does seem probable, and worthwhile, that the teacher highlights and directs learners to the hands as resources of information. In the classroom, the building of the gestured depiction may very likely need to take a modified structure illustrated in face-to-face interaction, but yet the achievement can still be the same.

Imagine a chemistry class where the instructor is explaining the particular configuration of a molecule when looked at from one perspective. She clicks off the power point, reducing competition for visual attention. She steps away from her podium into the space right in front of the first row of seats, manufacturing a sense of both students and instruction being in a shared space. Her hands face one another as she holds them up high in front of her. Her arms extend fully, giving the impression that the gesture is "for you". She makes it larger than if she were sitting across from one person. She says, "Watch my hands." Instead of using gaze (which would likely be lost in the larger setting) to direct attention to her hands, she explicitly directs attention through talk. She then goes on to present the hands as the depiction for the explanation of the concept. "My hands are the molecule". She, like the experts in face-to-face, proximal, dyadic and triadic explanations, presents the gestured depiction in full. She then proceeds to add details. As she extends her index fingers and her middle fingers she states, "My fingers represent the bonds to atoms". As she vigorously wiggles her index finger on her right hands and indicates toward it with a strong head pulse (rather than a slight gaze shift), she says, "This finger I am wiggling, this is the chloride". She keeps her hands up and gazes around the room. She presents the depiction in the absence of talk, giving students the

chance to look to it. Certainly the modification of practices and elements of practices distilled from the analysis of face-to-face interactions to highlight the gestured depiction in a classroom setting require a thoughtful adaptation that requires the instructor's awareness of the hands as a viable tool for explanation.

As the instructor gazes around the room, she will not be able to respond to every student's demonstration of the depiction, like she can to one person in face-to-face interactions. But she can certainly respond to a few. And if she sees any misunderstandings revealed in the hands, she can return to the depiction to add clarification, making the corrections available to the entire class. Once again, such principled uses of the hands and the body require an acceptance of them as valuable.

Certainly in face-to-face, proximal interaction some of these practices happen organically. They may naturally emerge because of the proximity of participant in interaction. Moving such practices that may more naturally emerge, as responses in face-to-face interaction to a classroom requires the explainer to explicitly and intentionally craft such practices into her pedagogy. Although not exactly the same as face-to-face, proximal interaction, such adaptation of practices allows the instructor to build the gestured depiction for the recipients, as the experts who were successful at building did in face-to-face, proximal interaction, and respond to some, but not all, of the students' demonstration. The data suggest that importing such practices into the class room will invite a different level of interaction to the classroom that may likely, in turn, support the development of conceptual understanding in this arrangement as it did in the face-to-face, proximal arrangement.

Passing the gestured depiction to the learner in face-to-face, proximal interactions requires some effort on the explainer's part. Some of the effort to insure that the gestured depiction is made of use by the learner is distributed to the practices the maker engages while crafting the depiction. For instance, a slight press of the depiction into the small interactional space between interlocutors sitting across from each other, followed by a pause to invite the learner to take the floor can do the work to achieve the transfer. And as the data show that when a learner takes up the gestured depiction in face-to-face interactions it results in the support of later learning. Certainly the same practices for delivering the gestured depiction to learners in large classrooms will not work. But what can be distilled and adapted for the different learning arrangement that can achieve the work of getting the depiction into the hands of the learners in the classroom?

Let's go back to the chemistry class. The instructor continues building the depiction, as she wiggles the index finger on her left hand, this time she holds the depiction up high as she looks out to the classroom and says, "This is bromide. And in this configuration, these atoms need to be across from one another". She extends her hands to the classroom thrusting her torso forward into the students' space and says, "See how they are across from one another". She then passes the depiction to the class by explicitly inviting the students to make the depiction in their own hands. "Now you create the molecule just like I did." A classroom of hundreds of students lifts their hands.

In order to encourage learners to engage the depiction as a thinking tool, the instructor goes on to ask, "Which one is your bromide?" Students begin to look to their own hands and move their own hands, experiencing the depiction as a perceptual resource to be viewed as well as felt in their own bodies. She again grazes the classroom

and looks for misunderstandings that can signal to her if she needs to highlight this again, continuing to use the depiction in the hands of the learner as her assessment tool. Once she is confident enough the students have taken up and accepted their hands as a molecule, she now pushes them to think through with the gestured depiction. To encourage students to use the depiction to think through ideas together she instructs them in their next move, “Now with the person next to you figure out where the atoms are in relationship to one another when you rotate the right side of the carbon backbone 30 degrees.” By simply passing the depiction out of her own hands as communicative tool for her students and putting the depiction in the hands of the learner and letting it be a thinking tool and interactive tool for them, she invites a different level of engagement that belongs now to the learners.

Transferring how gestures are used in face-to-face, proximal, dyadic and triadic interactions to the classroom oblige yet a higher level of crafting to make them of use for the teaching and learning. Although possible to carry the affordances of one-to-one, face-to-face interactions into the classroom, it certainly requires a different way of thinking about our talk and actions across such settings. As the research presented in this dissertation suggests that the effects of crafting gestural practices for and with participants promote learning in face-to-face arrangements, examining how this translates across different learning arrangement is a worthwhile investigation to support new design for classroom instruction.

Further Questions and Invitation for More Research

I believe that by having examined interactional activity across the use of the body that happens in face-to-face learning arrangements between experts and non-experts, I have offered claims that allow for a better understanding of the material and social resources used in the explanation of complex concepts. I have shown that depictions made by the hands and negotiated in interaction become vital aspects and prominent resources for explanation and understanding in face-to-face arrangements with two to three participants. Although offering an imagined narrative of how gestured depiction practices might be transferred to the classroom, I do not offer an empirical investigation of gesture use in such learning arrangements. I do, however, offer a useful platform for shaping such an empirical study. I believe important next steps in such research include investigating gesture use in a variety of learning arrangements. This will offer more insight into how gestures are shaped by, and function within, the social and material configurations, and thus further inform educational design and practices.

In moving the study of the role of gestures in interactional face-to-face arrangements to different arrangements such as the classroom also brings up other considerations worthy of study. That is, certain learning arrangements carry with them certain cultural expectations of behavior. A chemistry teacher does not usually wave her arms around in the classroom to show molecular configuration, although she may do so in face-to-face interactions outside of the classroom (as the data corpus shows). And even less likely, students in a large classroom do not generally move their hands and bodies. They watch the professor and take notes. Will a simple invitation from the professor in a classroom setting be enough for students to make the kind of use of gestures that Raya did sitting in a bar with someone telling her about polymer solar cell research?

Other than Max conveying concepts in dimensional geometry, all other experts in this study described concepts from chemistry, biology, and physics. The question emerges about the value and use of gestured depictions across different STEM disciplines. In all cases, concepts conveyed had a spatial dynamic, temporal property to them. Many depictions were often used, too, to make the invisible, visible. Do certain disciplines organically and effectively call up different kinds of gesture use in face-to-face interactions? This dissertation focused on a particular genre of gesturing – the depiction. Science seems to lend itself to this kind of gesture use. Other types of gestures, other than depicting gestures, may render an entirely different set of interactional exchanges and reveal a different role of gestures in teaching and learning. Understanding how different gestural practices serve teaching and learning across other disciplines only expands understanding of their complex affordances as well as constraints based on the discipline in which they are performed.

Participants in this project agreed on the shared goal of achieving understanding. What happens, as we often see in teaching and learning arrangements, when interests are not aligned but competing? How might this affect the efficacy of gestures to support explanations? How might this alter the functional distribution of the gestures if both participants are not working toward the same teaching and learning goal?

As the limitations of the study have rendered further questions, the current findings also give way to new questions worth exploring. For example, are some people better “disciplined” to successfully use gestures as teaching and learning resources? Both Mara and Max, professors at a university earned a distinguished teaching award. They also demonstrated effective use of gestures for teaching and learning. To recall, Mara

intentionally passed the hands-as-gill gesture to Steph to figure out the answer the question she posed. Under her guidance and throughout hands we worked out understanding. Max demonstrated practices of recipient design as he stepped out to take the learner's perspective on the depiction created for her. Did both these professors gain a sense of how to use the body in teaching and learning through extended experiences in teaching?

Also, most of the high gesturers in this study were involved in experiences that preferences the body. Raya, Ellie, and Katrina were professional modern dancers. I came to find out later that Sakina and Samantha both studied dance as a hobby. Bram played soccer in high school, and Max, who rode his bike to the interviews, talked about how he still enjoyed playing "Ultimate Frisbee" (Scopelitis Fieldnotes 5/19/2009). Perhaps bodies do learn how to be affected as they are engaged in activities that require attention to the body. As a result, it may be possible that people develop a pattern for perceiving movement in others and experiencing it in their own bodies that carries over into their own practices for explanation and learning. This, too, is a worthwhile and provocative study. Do people develop an epistemology about gestures as viable resources across other experiences? And if so, can we discipline teachers and learners bodies to be part of their practices for explanation and understanding?

Conclusion: Making Use of Gestures for Teaching and Learning

Savas, my son, (who may very well grow up to answer the questions this study raises), asked me to explain to him parts of "my book", as he calls it. As I began to read a section from my dissertation, he laughed and said, "Why are you just reading to me

when you can also gesture it to me”)? This is a worthy point to keep in mind as we move forward in the field of educational research. As the body has proven to be of importance in the process of explanation and understanding in the studies present in this dissertation, I encourage further development on ideas emerging from this project that continue to explore the role of the hands and the body in interactions for teaching and learning. As I come to close this project, it is evident to me that, in a quest to design opportunity-rich environments for teaching and learning, we must make use of all the available resources in each of us and in our world. This inquiry has provided further understanding of how the principled use of gestures and our body in interactions participates in teaching and learning. Such inquiry brings us one step closer to constructing more effective teaching and learning environments.

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