Chapter 8
Talking About Electricity: The Importance of Hearing Gestures As Well As Words

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8.1 Introduction

Constructivism has perhaps been one of the most influential contemporary approaches to understanding how children come to learn science in school classrooms. According to the constructivist perspective, children will have used their previous experiences to have formed some representations of many of the phenomena studied in school science (Driver et al. 1994). In her influential work, Driver proposed that these initial representations take the form of 'alternative frameworks'. Fundamentally, these 'alternative frameworks' provide children with explanatory scope and contain conceptual understanding that frequently contrasts with scientific explanations of the same phenomena; as such, they are subject to change when children begin their formal science education (Driver and Easley 1978; Driver and Bell 1986). Research investigating learning from this perspective has led to the development of a number of explanatory models identifying underlying mechanisms that support such 'conceptual changes' (e.g. Vosniadou and Brewer 1987; diSessa 1988; Karmilloff-Smith 1996; Sharp and Kuerbis 2006, summaries in Vosniadou 2008; Limon and Mason 2002). These models range in their depth and scope with some placing a high emphasis on purely cognitive processes (Rumelhart and Norman 1978; Posner et al. 1982), whilst others attribute a strong role to motivational and affective factors (Pintrich et al. 1993; Dole and Sinatra 1998). In addition, research associated with these individual models of conceptual change focuses on single areas of scientific phenomena. Vosniadou's weak and radical restructuring, for example, draws the majority of its evidence from astronomy teaching (Vosniadou and Brewer 1987).

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Biology concepts are the focus of Carey's (1985) weak and strong restructuring model. And the development of ideas of force studied in physics is the focus of diSessa's fragmentation theory (1988). Models also frequently lack consistency between the ages of participants recruited; notably, diSessa's original contributions came from college students, whereas Vosniadou's research recruited school age children. One criticism that is more fundamental originates from the lack of consensus regarding the level of mental representation studied. In some cases, the aim is to study individual concepts (diSessa 1988), and in others, mental models which result from theory structures are utilised (Vosniadou and Brewer 1987). Taken as a whole, this diversity of subjects studied restricts comparison and evaluation of models across scientific domains and prevents the models being evaluated for their utility in informing teaching across scientific curricula. A fundamental part of the current project was to address these criticisms by closely studying the development of children's ideas about electricity; however, the focus of this chapter is not on the evaluation of the models of change but on the importance that can be attached to different response types that children use when discussing their ideas.

Contemporary literature typically approaches the assessment of conceptual knowledge through largely verbal reports that are accessed through interviews or task-based activities (Osborne and Freyberg 1985; Primary Space Projects 1990/1994). This approach has been highly successful for mapping children's ideas for a range of science topic areas. One criticism has been the bias towards language and linguistic capabilities which may prevent a comprehensive understanding of children's knowledge particularly if children are not able to clearly or fully articulate what they know (Goldin-Meadows 2000). In order to overcome this potential bias, the work presented here investigates the development of scientific ideas and concepts from a multimodal perspective. The multimodal approach to understanding children's learning is developing rapidly. Initial findings from wider research adopting this approach have demonstrated that children utilise a number of different expressive modes; these modes include verbal dialogue, written pieces, drawings and other expressive art forms and non-verbal communication such as gesture, eye gaze and body posture during learning (Kress et al. 2001). Whilst Kress et al.'s research focused on how different modes of activity support children's acquisition of concepts in science, other researchers (e.g. Goldin-Meadows 2000) have investigated the role that non-verbal language such as gesture has in revealing children's existing conceptual knowledge. Crowder and Newman's (1993) study investigated the gesture and speech of thirteen children who were learning the science concepts associated with seasonal change. The results revealed that some gestures were 'redundant', others served to enhance the ideas expressed through speech, and in some cases, gestures served as carriers of scientific meaning that was not present in language. This led Crowder and Newman to conclude that 'as long as ideas outstrip scientific vocabulary, one can expect to see gestures used by elementary science students to carry unstated ideas' (p. 176). Further support for the importance of studying gesture can also be drawn from the work of Roth and Lawless (2002); this study highlighted how gestures can contain important information about children's ideas that are not contained in speech during discussions of knowledge. In a summary paper that drew on a body of research investigating different areas of children's problem-solving ability, Goldin-Meadows et al. (1993) suggested that stability between speech and gesture characterises a stable understanding of a concept; mismatch between the two elements characterises the time in which children are moving between conceptual understandings. It was argued that the 'gesture-speech mismatch signals to the social world that an individual is in a transitional knowledge state' (Goldin-Meadows et al. 1993, p. 279). This was a particularly attractive idea for the work undertaken and presented here as it highlights a window of opportunity through which it may be possible to capture the processes of conceptual change as it actually occurs and also an opportunity to explore how newly forming ideas are represented in gesture.

8.2 Children's Ideas About Electricity

Children's ideas about electricity have been a well-studied concept area (Osborne 1981, 1983; Solomon 1985; Cosgrove and Osborne 1985; Bell 1991; Osborne et al. 1991; Borges and Gilbert 1999; Finkelstein 2005; Glauert 2009). However, at the time that this work was undertaken, there was little evidence of such a study adopting the multimodal research approach. Studies of children's ideas about electricity typically elicited children's ideas and coded their responses thematically in order to capture the underlying frameworks of understanding applied. Many studies then compared within and between the different age groups in order to consider how ideas may have changed over time. The results drawn from this body of work appeared to suggest broadly similar outcomes for different age groups. In addition, studies have explored children's ideas in a range of different countries including the UK, mainland Europe and New Zealand. For example, three typical studies include Shipstone (1985), Osborne et al. (1991) and Borges and Gilbert (1999); these studies are briefly reviewed here as these outcomes were used in this work in order to guide a framework analysis that was undertaken.

According to Shipstone (1985), five models of understanding were evident in the responses of children between 12 and 17 years of age:

- A unipolar model – no current returns to the battery.
- A clashing currents model – current flows to the bulb from both terminals of the battery.
- An attenuation model – current flows around a circuit in only one direction and is used up in the bulb.
- A sharing model – where there is a series circuit, the current is shared between the components.
- A scientific model – where there is an understanding that current travels in one direction through a circuit and is conserved.

In his summary of findings, Shipstone suggested that the younger children were more likely to discuss their ideas of electricity with reference to the unipolar and the clashing currents models but the prevalence of these models dropped as children got older. Notably in this work, it was indicated that 60 % of the 17 year olds involved used a scientific model but this figure fell to less than 10 % of the 12 year olds.

Osborne et al. (1991) explored ideas about electricity and conductivity with children between the ages of 5 and 11 years. Interestingly, the results also revealed some surprising findings regarding the children's drawings of simple circuits. These are summarised as follows:

- A single connection – where children drew in one wire to connect the battery to the bulb
- Two battery connections, one device connection – where children drew in two connections at the battery but failed to acknowledge that the wires needed to connect to separate points on the bulb
- Two battery connections, two device connections – where children used the correct number of connections at both the battery and bulb but these were in the wrong place
- Two correct connections shown – where the children place the wires appropriately
- No response – where the children failed to respond to the drawing tasks

Borges and Gilbert's study (1999) aimed to expand on the models of understanding that had been identified by earlier work by involving older participants including professionals (e.g. electricians). As might have been anticipated, outcomes included presentation of electricity as moving charges and electricity as a field phenomenon. However, the presence of such complex understandings is rarely found in studies with children. Overall, these models highlight the notion that ideas about electricity can be categorised according to specific models that vary in complexity depending on the age and experience of the participants. The three frameworks suggest that early understandings of electricity may reveal the importance of connections between the battery and the bulbs but may not acknowledge that the current within a circuit is conserved or that a return path is important. As ideas progress with age and experience, these become more scientific until concepts such as electrons and moving charges are incorporated.

These important studies underpinned the work undertaken in this project, and during the analysis phase, the researcher explored whether these models were present within the data drawn from the sample, whether additional models were present and whether children used one coherent model throughout the activities or whether they applied different models at different times.

8.3 Rationale

The whole research project specifically investigated the following research questions:

- Does a multimodal analysis of verbal and non-verbal communication facilitate an understanding of children's ideas in science?

- Can such analyses be utilised in order to explore and contribute to an understanding of the dynamics of conceptual change?
- Do outcomes from the work in this thesis have any classroom application?

These research questions did perhaps also propose an overarching question regarding whether or not it was possible to apply a multimodal research lens to the issue of conceptual change in science education. However, this chapter attends to just one of these questions and explores the types of gestures that children used when discussing their ideas about electricity, typical gestures produced during discussions and what importance was attached to understanding these in order to fully appreciate children ideas holistically.

8.4 Method

The research presented here utilised a cross-sectional design by studying the scientific ideas and concepts of three groups of children aged 7, 11 and 14 years in English primary and secondary schools. A total of 93 children took part in the study; the children were distributed as follows across the three age groups: 34 Year 2, 44 Year 6 and 15 Year 9. The participating children were briefed that the researcher was interested in their ideas about electricity; the children were all informed that they would be video recorded, and verbal consent was obtained prior to the activities being undertaken. All of the children participating in the study completed practical science activities in electricity; the study used the same activities and question probes for all three age groups. The practical activities were designed to elicit children's ideas by probing understanding as they completed familiar tasks (e.g. the construction of simple circuits) whilst subsequent tasks were designed to challenge existing ideas (e.g. an analogy of electron movement in a simple circuit using 'smarties'). These activities permitted the analysis of both existing ideas and concepts and the opportunity to observe the outcome when concepts begin to change or are challenged.

The science activities took place in small groups (approximately five children of the same age in each group, for the most part, the groups were of mixed academic ability). The activities were highly contextualised to the concepts studied, were interactive and dialogic in nature and included protocols from participant observation and interview-based methodologies. Each practical science activity lasted approximately one hour. All were audio-video recorded in order to capture events fully and to obtain gesture in transmission.

In order to explore the potential role of each response type, the transcription and the subsequent analysis focused on the modes and areas shown in Fig. 8.1.

Transcripts coded both verbal and non-verbal responses collected during the beginning and the end of each of the sessions; in addition, three group studies (one from each age group of children studied) were fully transcribed for subsequent analysis. The beginning and end of discussions were transcribed fully as these parts

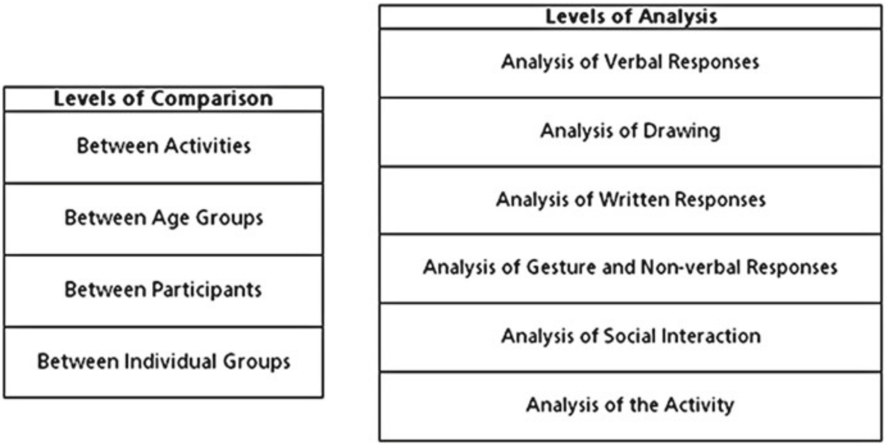


Fig. 8.1 The different levels of comparison and analysis explored in the study

of the activities included direct probes on the children's ideas about electricity (e.g. what do you think electricity is?); therefore, this data was used to pinpoint which model or models of electricity the children were using, and it was anticipated that the before and after comparison would permit the capture of any changes in ideas or frameworks applied or whether frameworks were used consistently. Analyses of the data included both within and between age group comparisons for children's ideas and concepts related to each of the science topics. Verbal and non-verbal data were interpreted using a content analysis approach (Krippendorff 2012), and previous models about electricity were used as a guide in order to categorise the children's ideas into frameworks. The verbal and non-verbal data was also compared in order to capture matches and mismatches between the two forms of communication. The results to the content analysis were discussed at length with the author's supervisor for the project, and the supervisor also supported the interpretation of the gestures in order to address issues of reliability.

8.5 Results

The results drawn from the study are discussed here in terms of the types of gestures that children used when discussing their ideas about electricity, the typical gestures that children produced and the importance that may be attached to these in terms of revealing aspects of children's ideas that may not be contained in other response types. The overall results regarding the frameworks of understanding that the children used and applied during the activities were largely congruent with the previous research of Shipstone (1985), Osborne et al. (1991) and Borges and Gilbert (1999). For example, the older children demonstrated the more scientific ideas about electricity, whilst the younger children frequently discussed electricity in terms of its purpose (see Fig. 8.2).

	Category	Year 2 (N = 34)	Year 2 (N = 34)	Year 6 (N = 44)	Year 6 (N = 44)	Year 9 (N = 15)	Year 9 (N = 15)
		Before	After	Before	After	Before	After
Intuitive --------> Scientific	1 Non-relevant and Non-Scientific						
	2 Unipolar Model	4 (12%)	1 (3%)	5 (11%)			
	3 Two-Component / Clashing Currents Model	21 (62%)	21 (62%)		1 (2%)		
	4 Closed Circuit Model	9 (26%)		39 (89%)		15 (100%)	
	5 Current Consumption / Sequence Model		9 (26%)				4 (27%)
	6 Constant Current Source / Sharing Model		3 (9%)		42 (96%)		8 (53%)
	7 Ohm's / Scientific Model				1 (2%)		3 (20%)

Fig. 8.2 The models about electricity that the children used at the beginning and the end of the electricity activities

What was particularly interesting were the gestures that the children had during their discussions and the way that these could reveal ideas that were not contained in any other response types (e.g. verbal language, written responses or drawings). These gestures were often fundamental to allowing the researcher to pinpoint which model of electricity the children were applying.

8.5.1 Types of Gestures That Children Used

The gestures that the children produced when discussing their ideas about electricity were transcribed and analysed for their content. The analysis revealed that of the different groups, 31 Year 2, 38 Year 6 and 11 Year 9 children used gestures during their discussions. The children used five different categories of gestures; these categories were consistent with the previous work of Callinan and Sharp (2011) which showed that children used both scientific and social gestures (see Fig. 8.3 for full details on the five categories). Callinan and Sharp's paper (2011) had analysed data from a pilot study that had been conducted in order to develop the methodology for the research undertaken here; this work had explored if children used gestures in their discussions of science ideas and what information these gestures had contained in order to ascertain whether this would be useful for revealing a more

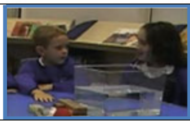
Scientific Gestures		
Type of Gesture	**Definition**	**Example Photograph**
Referential	Pointing to objects, pictures or people in order to complete / extend discussions of ideas	
Representational	Acting out the behaviour of objects, people or events in order to show how something works or happened	
Expressive	Using the hands to represent values such as the strength of responses in objects, people or events in order to show how they think they work	
Thinking	Including finger drumming, head holding, face and hair stroking – used when considering how to respond to a question, problem or situation	
Interpersonal Gestures		
Type of Gesture	**Definition**	**Example Photograph**
Social	Eye contact, body movement, touching or nudging others – used to elicit a response from other members of a group	

Fig. 8.3 The five categories of gesture that children use when discussing their science ideas (Callinan and Sharp 2011)

holistic understanding. The analysis here focused on a new sample of children and thus could confirm the presence of the different categories of gesture and the application of these across a larger sample of children in order to support or extend understanding of the ideas and knowledge that the children had.

Scientific gestures contained information about the ideas that children had, whilst social gestures were informative about the social aspects related to learning (e.g. how peer support was elicited when discussing ideas). It is proposed that both are important if we are to understand children's ideas holistically.

Examples of gestures that the children produced included Mike in Year 2 boy who used a referential gesture to add to his discussion of his circuit drawing. As he discussed the content of his drawing, he pointed to where he thought a bulb holder should appear; it was possible to have a clearer understanding of what he thought should be included in the drawing and where by attending to this gesture. The responses of Rachel, a Year 6 child, showed that in her speech, she described electricity using its function (e.g. that it powers things); however, her representational gesture (a circular motion drawn with her hand) demonstrated that she also had an awareness that electricity flowed through the circuit too, and the gesture also showed how she thought that this occurred. Expressive gestures were used by the children in order to show the values such as the strength of responses, for example, how the light from a bulb would appear. In one example, a Year 2 child, Selena, used just such a gesture in order to show how she thought the light would behave once she had completed her circuit; her repeated hand movements were used to reflect the intensity of the light that she expected to see once her circuit was complete.

8.5.2 Typical Gestures Produced

During the electricity tasks, the children across all three age groups used representational gestures in order to draw out paths showing how they thought the electricity moved in a circuit (Fig. 8.4). As shown in Fig. 8.4, the child either used their fingers to trace a path above the circuits and their whole hands or in some cases both hands to draw paths that followed the wires in the circuits that they had built. These gestures, considered representational because it is proposed that these were used to show how the electricity moved in the circuit, were particularly useful in this context for revealing the underlying models about electricity that the children held. For example, some children stopped the gesture once they reached the bulb, whilst other continued the gesture back to battery, and on other occasions, children drew out continuous circuits representing that they believed that the electricity did not stop; it just continued to 'flow'. It is proposed that these gestures revealed specific

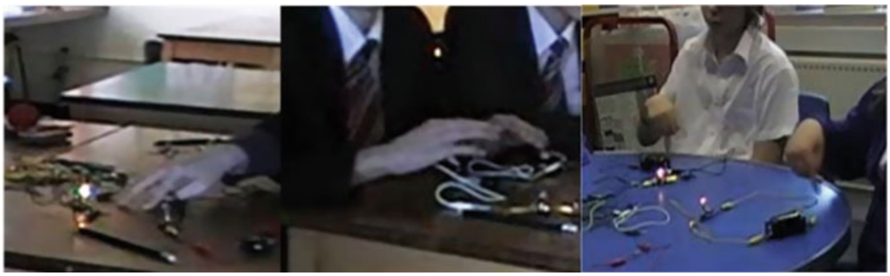


Fig. 8.4 Typical representational gestures that occurred across the three age groups of children during their discussion about circuits. The gestures represented the ways that the children thought the electricity moved through the circuit

and fundamentally different frameworks for understanding electricity. In addition to the representational gestures, children frequently use referential gestures to point to objects during their discussions, often without naming the referent object, and as such, the gestures formed an important aspect of their communication about ideas. Thinking gestures were used by some children in order to indicate that they were considering their responses, and these gestures took many forms and included finger tapping and hair stroking.

Social gestures were also used during some discussions in order to elicit ideas from other members of the groups or to clarify whether there was agreement for the ideas being discussed. These gestures were interesting because on some occasions, these resulted in children stopping their discussions and waiting for other group members to complete or complement what they had said.

8.5.3 Frequency of Gestures for Electricity

The prevalence of the five categories of gesture is show in Table 8.1. The analysis revealed that within the context of the electricity activity, referential and representational gestures were used the most frequently across all of the age groups of the children. However, there was also evidence of expressive, thinking and social gestures occurring within the context of these activities even though these gestures occurred less frequently.

When exploring the differences between the age groups, it appeared that the Year 2 children used the most referential gestures in their discussions; frequently, these included pointing to objects rather than naming them. The same age group also used representational gestures frequently; these tended to be when the children used their hands to act out or represent objects or actions. Such use of representational gestures may have occurred because of the complexity of the language required to explain some aspects of their understanding of electricity. Thus, the gestures served to expand on the ideas available in verbal language. The Year 6 children used representational gestures more frequently than any other age group and any other form of gesture. As with the Year 2 children, these gestures often comprised of the children using their hands to represent objects or actions. This age group also appeared to use social gestures more frequently, and although this may have been a feature specific to this group of children, the social gestures were often used in order to offer support to each other. Finally, the Year 9 children most frequently used referential gestures,

Table 8.1 The number of gestures used by the different age groups of children during their discussions about electricity

Types of gesture	Referential	Representational	Expressive	Thinking	Social	Total
Year 2	38	33	6	8	15	102
Year 6	21	48	18	4	31	122
Year 9	23	15	4	5	15	62

including pointing. As with the Year 2 children, these gestures often referred to objects that the children did not name and appeared to be used to complete verbal discussions. However, it is important to remember that there were some differences in the number of participants in each age group and this may in part explain some of the differences in the number of gestures observed.

8.5.4 What Gestures Add

The results drawn from the analyses undertaken in this work revealed that children used gestures in a number of ways. Interestingly and in contrast to Crowder and Newman's (1993) work, none of the children taking part in the activities used redundant gestures. All gestures appeared to either compliment the content of the verbal and written responses or contain important conceptual information that was not included in the other response types. For example, some children would discuss how electricity moved in a circuit and then accompany this discussion with the representational gestures discussed in the previous section. These gestures were fundamental for revealing the underlying frameworks of understanding about electricity that the children had and helped the researcher to locate the children's ideas within the different models about electricity. In the example shown in Fig. 8.5, the gestures were fundamental for highlighting that once the task changed, (e.g. the number of bulbs included in the circuit) the mental models used to explain how the electricity would travel were also revised. Interestingly, the verbal response produced by Daniel in Year 6 (the child wearing the blue top in Fig. 8.5) remained similar on both occasions; he simply discussed the way that he thought the electricity moved. However, his gesture changed from a single-handed representational gesture that traced a clockwise path around the circuit to a two-handed representational gesture where both hands traced opposing paths beginning at the battery and ending at the bulbs. These gestures revealed the application of two different models about electricity; therefore, this and other examples of this type of response collected during this work helped to illustrate the importance of attending to gesture in order to fully understand the ideas that children had.

Fig. 8.5 Daniel's representational gestures which reveal his underlying ideas about electricity moves in a circuit with one bulb and with two

8.6 Application in Context

It is proposed that the results drawn from the analysis undertaken here have application for teaching and learning, assessment, curriculum development and teacher training. Importantly, in many teaching environments, the significance of gesture is often overlooked, perhaps due to time constraints and other demands when working with larger groups of children, and as shown in this study, important clues and cues to children's ideas can be contained within these. With reference back to the constructivist literature, Ausubel (1978) highlighted the vulnerability of verbal responses when accessed in order to explore the development of children's conceptual ideas. Notably, Ausubel et al. (1978, 102) stated that:

> Since there is often a time lag between the correction of misconceptions and the revision of language usage, it cannot be assumed that conceptual confusion necessarily exists in all instances where words are used inappropriately.

This important discussion highlighted a fundamental critique of the traditional approaches that had been used to measure children's knowledge and indeed can be seen as a criticism of many current teaching and learning and assessment practices. Ausubel further proposed that language alone as a medium may not be enough if researchers and teachers are to understand fully the ideas that children have.

> Prior to being verbalised, new concept meanings also typically exist for a short while on a subverbal level – even in sophisticated older learners. (p. 105)

Such a notion is particularly resonant with the work in this paper which adopted the principles of multimodality, e.g. that knowledge can be held and indeed demonstrated in a range of ways including through gesture. Importantly, language may not always be the best medium to assess conceptual ideas, and gestures can help to locate children's ideas within different models of understanding about electricity such as those identified by Shipstone (1985).

8.7 Conclusions

The work undertaken here supports the notion that a multimodal analysis of children's ideas adds positively to the existing body of literature which aims to provide an understanding of children's ideas for different science concepts. Gestures can contain additional conceptual information that is not contained in any other response type such as verbal or written responses and drawings, and this can help researchers and indeed teachers to appreciate, interpret and understand the ideas that children have for different science concept areas as well as to help locate those ideas within different models of understanding. The analyses undertaken in this project also highlight that the social gestures that children use can be particularly revealing about the impact that peers can have on children's knowledge growth, the way that concepts are negotiated when undertaking collaborative work and the information that children are comfortable with revealing when their ideas are probed in a group context. It is suggested that future research should aim to incorporate such detailed analyses of gesture in order to provide a holistic overview of children's ideas. It is argued that gestures illuminate meaning and reduce ambiguity associated with other response types such as language. Gestures are a useful form of non-verbal communication particularly when language and linguistic skills are underdeveloped.

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