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Stuck for Words: Multimodal Representations of Children's Ideas in Science

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Abstract
Research which has aimed to understand how children come to acquire ideas about different science concepts has had a long history [1, 2, 3]. However, these studies have explored conceptual knowledge largely through verbal reports. Whilst these approaches have been successful in revealing what children know the bias towards language and linguistic capabilities at the expense of other forms of communication may prevent a comprehensive understanding of knowledge growth particularly if children are not able to clearly or fully articulate their ideas [4]. This paper uses the results to recent study to discuss how children use gestures and other forms of non-verbal communication in order to demonstrate science ideas that may not appear in their verbal or written language. The results reveal that children frequently use gestures; these gestures can be categorised according to their content [5] and can be task specific or situated in the context of the science topic. Importantly, the content of children's gestures can change once children's ideas are challenged using science activities even if their verbal responses do not. These findings help to demonstrate the significance of analysing children's gesture particularly as the content can be important for revealing children's knowledge.

1. Introduction
Constructivism is one of the most influential contemporary approaches to understanding how children come to learn science in school classrooms. The constructivist perspective proposes that children will have formed some representations of many of the phenomena studied in school science based on their previous experiences and reflection on those experiences in order to understand the world around them [2]. These initial representations are proposed to take the form of 'alternative frameworks' rather than misconceptions because of the explanatory scope that they provide children with. These 'alternative frameworks' contain conceptual understanding that frequently contrasts with scientific explanations of the same phenomena and are therefore subject to change when children begin formal science education [3, 6]. 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' [1, 7, 8, 9,10]. These models range in their depth and scope with the research associated with each individual model of conceptual change focusing on single areas of scientific phenomena and different participant groups. Furthermore, contemporary literature typically approaches the assessment of conceptual knowledge through verbal reports that are accessed through interviews or task-based activities [11, 12]. Whilst this approach has been successful for generating a wide body of understanding the bias towards language and linguistic capabilities may prevent a comprehensive understanding of children's knowledge particularly if children are not able to clearly or fully articulate what they know [4]. 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 for understanding children's learning is a new, innovative and rapidly developing research area. Initial findings from wider research adopting this approach have demonstrated that during the course of their learning children utilise a number of different expressive modes in order to acquire conceptual knowledge. 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 [13]. Whilst Kress et al's research focused on how different modes of activity support children's acquisition of concepts in science other researchers [4] have investigated the role that non-verbal language such as gesture has in revealing children's existing conceptual knowledge. One early analysis conducted by Crowder and Newman [14] 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). In a summary paper that drew on a body of research investigating different areas of children's problem solving ability [15] it was suggested that stability between speech and gesture characterise a stable understanding of a concept, contrastingly 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"* [15, p.279]. Using the literature discussed above as a guide the study discussed here utilised a multimodal approach, whereby the analysis focused on verbal and written discussions as well as the content of non-verbal communication such as gesture in order to explore what children's gestures may reveal about their ideas that were not communicated in language based responses. Furthermore it was examined whether such analyses could contribute to the understanding of conceptual change.

2. Rationale

This project specifically investigates 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 this work have any classroom application?

3. Methodology

The research presented here utilised a cross-sectional design by studying the scientific ideas and concepts of three groups of children aged seven, eleven and fourteen years in English Primary and Secondary schools. A total of 101 children took part in the study, the children were distributed as follows across the three age groups; 34 aged seven, 44 aged eleven and 15 aged fourteen. All of the children participating in the study completed two practical science activities, one in electricity and one in floating and sinking. The practical activities were designed to elicit children's ideas by probing understanding as they completed familiar tasks (for example, testing different materials in order to explore whether they would float or sink) whilst subsequent tasks were designed to challenge existing ideas (for example, pushing an inflated balloon into water in order to feel the upthrust force generated). 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 practical science activities took place in small groups (approximately five children of the same age in each group). The activities were highly contextualised to the concepts studied, 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.

4. Results

The data demonstrated that children used five different types of gesture, these gestures contain both scientific and social information [5]. Scientific gestures came in four main forms:

- referential – e.g. pointing to objects, pictures or people in the immediate environment;
- representational – e.g. re-enacting the behaviour of objects, pictures, or people;
- expressive – e.g. often including repetitive movements or building on representative gestures revealing the values associated objects, pictures or people;
- thinking – e.g. finger drumming, waving hands, head holding or face and hair stroking.

While scientific gestures appeared to play a crucial role in facilitating understanding of children's scientific ideas, social gestures also had an important role for facilitating our understanding of how young children used input from peers in order to structure their responses to probes of knowledge or seek social support when they were experiencing uncertainty or difficulty in generating a response. During the course of this study there are many instances which demonstrate how children have used such non-verbal approaches to eliciting help from each other. In one example, 'Sam' (7 years old) used a social gesture whilst discussing his ideas related to floating and sinking. As he spoke Sam paused mid-sentence, moved his head to look in turn at each of his neighbours, and after receiving no response from them, he continued to speak. This gesture was interpreted as Sam's non-verbal way of exploring whether these was agreement for his ideas within the other members of the group. Whilst these gestures can be interpreted as demonstrating little information regarding children's scientific understanding they are particularly helpful for revealing how children negotiate meaning in groups.

Scientific gestures appeared to have a fundamental role in the children's communication of their scientific ideas. For example, the younger children frequently used referential gestures in order to point to objects that they did not mention by name or directly discuss (e.g. the bulb in a circuit or an object that they thought would float). The analysis revealed that these gestures were helpful for completing children's discussion and served as carriers of meaning which helped to add depth to the interpretation of their responses. Representational gestures were also often used in order to complete articulation of ideas and children frequently used these to convey information that was not contained in speech. For example, some children used their hands to represent the path that they thought electricity would take through a circuit whilst their verbal descriptions will just say 'it (electricity) goes like that'. The data demonstrated that although children frequently give similar verbal response, the children drew three distinct forms of paths to represent the 'flow' of electricity in the circuit. Some children use one hand to draw a path that began at the battery and followed the wire before stopping at the bulb. Other children used one hand to draw paths that began at the battery, followed the path of the wire to the bulb before continuing around the second wire and stopping at the battery. Finally, some children use both hands to draw paths that began at the battery, each hand then followed a different wire until they met at the bulb and stopped there. This final example was resonant of the 'clashing currents' model discussed in the research literature [16]. It is proposed that results such as these support the need for a more detailed analysis of children's gesture and support the view that children's gesture can indeed reveal vital information about children's ideas in science. Expressive gestures appeared to add to this evidence by showing, for example, how a bulb would be brighter if more batteries were added to a circuit.

The analyses also revealed that when existing ideas were challenged through practical science activities some children began to immediately incorporate the new ideas into their existing schema whilst others appeared more resistant to the new explanation. Changes in ideas were observed in the children's verbal responses following participation in the activities, however, in some cases the change in ideas was also observed in the gestures that children produced and on some occassions were only observed in the gesture (with the verbal response remaining the same). For example, Daniel (11 years old) demonstrated a change in his non-verbal gestures following the challenge of his ideas. At the beginning of the activity Daniel's gesture related to his ideas of sinking was as follows, he used his left hand, which was held flat with the palm facing downwards, to make a downward sweeping motion. After Daniel's ideas had been challenged through our demonstration of upthrust and water displacement his gesture changed so that his hand was held flat palm facing upwards and he used this hand to made a downward movement (see figure 1). This change in gesture appeared to illustrate how he had now incorporated ideas regarding the forces involved in sinking into his explanation. His initial gesture appeared to indicate that he located the force which makes the object sink as acting from above. However, after of our discussion of upthrust his gesture was altered so that it reflected the supportive force that is located from beneath the object.

Fig.1: Daniel's change in gestures as shown at the beginning and the end of the floating and sinking activities.

5. Discussion

It is proposed that the multimodal, task-based approach offered a more comprehensive route for studying children's existing ideas and concepts of the scientific phenomena associated with electricity, and floating and sinking. It is also suggested that verbal analyses of children's responses to probes regarding their ideas used in isolation are insufficient on their own and can lead to biases in results that may fail to account for children's actual knowledge and result in the misclassification of the underlying frameworks that the children hold. Such a vulnerability can impact on the accuracy of findings related to models of conceptual change, however, the application of this approach may reveal a more holistic interpretation of conceptual change. The multimodal approach is particularly helpful for understanding younger children's ideas especially when they find it difficult to articulate their ideas and concepts coherently or fully.

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