The Meaning of Action in Learning and Teaching

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Abstract

Action is a highly theorised aspect of social life nonetheless it remains a relatively neglected source of data within educational research. This paper attempts to highlight the significance of the analysis of organised action within educational research. It describes and demonstrates an analytical approach to action applicable to the classroom developed from approaches to the analysis of bodily communication and action in drama education (Franks, 1995 & 1996) and from new approaches to rhetoric developed in the research project 'Rhetorics of the Science Classroom' funded by the ESRC (Kress, Jewitt, Ogborn & Tsatsarelis, forthcoming). These approaches draw on social semiotic theories of making meaning in order to describe the complex relationship between the semiotics of social action and the situated experience of learning in the classroom. This paper describes how action realises meanings and shapes classroom interaction through the application of the schema to video data from a science lesson on energy with year nine pupils (14 years-old). Finally, it draws attention to the research and pedagogical implications of a focus on action in the science classroom and in education more generally.

The Meaning of Action in Learning and Teaching

Action in the classroom

We are interested here in the action of teachers and learners because we believe the physical action of socially organised persons is a powerful mode of realising meaning in classrooms. We view learning as happening when people act *in* and *on* the world. In concentrating on physical activity and its role in learning and teaching, we do not wish to downplay the importance of the role of verbal (or visual) modes of making meaning, nor do we wish to atomise the making of meaning into its constituent modes. Rather, we see these separate semiotic modes as integral, interactive and, depending on specific actions in different contexts, differentially important in the social construction of meaning. Our suggestion is, however, that relatively little attention has been paid hitherto to the role of physical action in the description and analysis of learning in educational research. The purpose here is to privilege the role of physical activity in learning in the hope that it might be taken into account, together with the role of language and other semiotic modes, in researching the processes of learning and the development of thinking.

Science lessons are particularly useful examples because, perhaps more than many other curriculum subjects, learning in science frequently involves pupils getting out of their seats, grouping themselves around benches, interacting with materials, equipment and each other. The importance of action in school science is firmly rooted in the history of science education and more generally in the history of science. It is also embedded in the National Curriculum, and the Nuffield Curriculum Projects over the last three decades which have emphasised the importance of practical work in school science. However, the high status of action in the science classroom does not appear to be reflected in educational research that has tended to focus on teaching and learning as primarily linguistic accomplishments.

Through observation and analysis of action in science lessons over time, observing the constant dynamic flow of bodily action in the semi-articulated episodes that constitute the science lesson, patterns emerge in terms of iterated and reiterated (or *routinised*) activities and practices, the

arrangement of time (rhythm), spatial arrangements and so forth. These patterns are made visible to observers and analysts through the physical presence, co-presence and co-agentive activity of teachers and pupils.

Towards a definition of action

We see action as a global undertaking of the person (see Greimas 1987: p. 26). Meaningful action can be seen as structured, transformational, communicative and generative. It follows that, if we are looking at how teachers teach and pupils learn we can examine patterns of action as evidence of learning. As a global undertaking of the person in a social and interactive context, action is clearly a complex phenomenon. At its widest definition, human socially orientated and meaningful action includes verbal action as well as other modes of bodily communication (such as gesture, posture, 'face-work', movements in and through space and so forth).

Our work is located in what can be described as the 'sociocultural field'. Our description and analysis of human physical action is firmly situated in the sphere of human relations and interaction contextualised within institutional settings such as schooling. We see human action as being shaped more by social and cultural aspects of human existence than it is by biological factors. The notion of 'field' is to indicate that we draw on work from the various disciplines of social semiotics, cultural psychology and cultural anthropology that give us different perspectives on action. They are compatible in terms of their view of the social construction of meaningful human activity. From within the sociocultural purview, 'the general orientation is to view action as being organised or shaped by several *analytically distinct but interacting influences*' (our emphasis, Wertsch, 1995, pp. 62-3). Further, the sociocultural approach emphasises that there is a direct, reciprocal and developmental relation between activity in the realm of physical social interaction and the realm of the inner mental activity of individuals.

There are two steps that we should make that would help to give a clearer definition of the way that we are approaching action: first, to distinguish between action and behaviour, and second, to make a

distinction between action and activity. In the first place, following Weber's distinction, to describe what people do without reference to their subjective motivations or interpretations can be seen as reactive or responsive *behaviour* (see Reynolds, 1982: p. 329). If, however, we interpret what people do as being motivated, interested and meaningful, we are describing *action*.

In the second place, a brief exploration of the distinction between action and activity will help us to develop a view of the located classroom actions of particular individual learners in relation to wider concerns of learning in institutional settings. Here we draw heavily on the work of Russian psychologists Leontiev (1981) and Vygotsky (1978 & 1986), and especially from the ways in which their ideas have been developed in recent work (e.g. Wertsch *et al*, 1995, and Cole et al, 1997).

Leontiev states that 'an act or action is a process whose motive does not coincide with its object (i.e. with what it is directed to), but lies in the activity of what it forms part' (1981, p. 401). Whereas the activity of 'higher animals is governed by natural material connections and relations', human activity 'is governed by connections and relations that are *primordially social*' (Leontiev, 1981, p. 212, our emphasis). In recent interpretations of the concept of an activity system, it 'is seen as a collective, systemic formation that has a complex mediational structure. Activities are not short-lived events or actions that have a temporally clear-cut beginning and end. They are systems that produce events and actions that evolve over lengthy periods of sociohistorical time. The subject and object are mediated by artefacts, including symbols and representations of various kinds' (Cole *et al*, 1997, p. 4). This view expands on Leontiev's idea that human activity is generated out of the triadic relation between a (human) subject, the use of a mediating device (or tool) and a particular object or goal. It gives emphasis to the relation between this 'subsystem' (the subject-mediator-object relationship) within the wider context of historically developed social rules (norms and conventions) and communities sharing common purposes, whose tasks are differentiated to achieve these purposes (division of labour). Finally, 'various components of an activity system do not exist

in isolation from one another; rather they are constantly being constructed, renewed, and transformed as outcome and cause of human life' (Cole, 1996, pp. 140-1).

If we apply this idea in a general way to the actions that took place in the science lesson described below in more detail, we can illustrate the meaning of the distinction between particular action and the classroom as an activity system. Here, we find learners engaged in the experimental burning of different fuels. The direct object of the action appears to be to measure the temperature that water can reach if it is heated by specific quantities of different fuels. The task is mediated by verbal language (teacher instruction, worksheets, pupil discussion etc.), teacher demonstration, images and various bits of equipment. Yet these actions are set within the wider context of the institution of schooling and the particular context of the science classroom as an activity system which permits specific actions.

Science classrooms are social locations that have developed and emerged as 'communities' over historical time, both on a macro-level in terms of the development of schooling and on the micro-level in terms of the history of that particular school, the science department within it and so forth. There have developed norms and conventions of schooling and of the science classroom, and there are divisions of labour between, for example, teachers and learners or between groups of learners themselves. In these locations pupils and enact the 'science lesson' as they engage with the expectations and possibilities of the activity system.

In our example of pupils doing science we find that specific tasks are divided among different members of the group. In setting up the experiment, for example, we find pupils A. and B. involved in the business of finding the correct clamp to hold a thermometer in place. This relatively protracted sequence of action—finding the clamps, trying to attach them to the stand, failing to do this, searching and finding the correct clamps—makes little sense as a sequence in itself. The direct

object of this sequence is to attach clamps to a clamp stand, but this only makes sense if the pupils understand it as a necessary part of the wider sequence of actions. In this case measuring the relative effectiveness of different fuels fits into the processes of doing investigations, either as part of the classroom activity system of school science or in the field of scientific method in the activity systems of the wider world. To do an investigation as part of a lesson, or as part of doing science, one needs to use the tools of science appropriately.

As groups and individuals, therefore, the pupils' actions are partly governed by the (historically shaped) rules of the science lesson as an activity system and, at the same time, their actions construct, renew and transform the doing of school science. Looking at an individual's or a group's action within the wider context of patterns of action that are possible within the lesson as an activity system allows us to see how a social subject transforms the object through the processes of mediated action (Cole, 1996, p. 140). It is through looking at how the processes of mediational action *transform* the objects of action that we might be able arrive at a view of how action relates to learning and the development of mind.

As we have suggested, it is possible to view language as a mode of action. At the most basic level, language, gesture and movement are particular kinds of muscular action. These actions are, in their turn, activated and controlled by levels of mental action that emerge through the processes of internalisation and the development of thinking (see McNeill, 1979, pp. 6-7). However, if we follow McNeill's work on the conceptual basis of speech, we can see, for example, that speech and gesture have different (albeit complementary) functions in relation to conceptual thought, and thus are different modes, each having a different relationship to the making of meaning (1979, pp. 254-277).

By extension, therefore, we shall be viewing physical action and language as distinct modes, each of which offers particular options (choices, affordances and constraints) for making meaning. In this, we see action as a partially articulated semiotic system which, in reciprocal and dialectical relation, continually both realises and constructs the social world in both thought and deed. We say 'partially articulated' because, although we see action as organised and structured, this structure is not equivalent to the grammatical structures of language (again, McNeill's work on the relationship between language, gesture and concept, cited above, points to this). Action takes place in specific contexts; it is always located in particular settings and in specific histories, both on a micro-level (personal, particular class, specific school etc.) and a macro-level (the history of educational policy, or pedagogical practice, for example).

A key component of the sociocultural framework we use draws from social semiotics. This allows us a perspective on physical action that sees it as socially organised, sign-making activity that is a key component in constructing meaning, both in internal psychic domains and in the social world. Here, we refer to work originally developed on language by M. A. K. Halliday (1985 & 1978) who identified three overarching functions of language (or 'metafunctions'). When we make meaning (in any semiotic mode) we simultaneously construct a presentation of something (*ideational* metafunction), orient it to others (*interpersonal* metafunction) and, in so doing, we create an organised structure of related elements (*textual* metafunction) (Lemke, 1998). In the introductory chapter of their book *Social Semiotics* (1988), Hodge and Kress describe the way in which the field emerges out of a critique of 'mainstream semiotics' that privileges a view of the product and system of communication over the social and interactive contexts in which communication takes place (1988, p. 1). The 'functional' approach has been elaborated to take account of modes and forms of making meaning other than verbal language, including images and artefacts (Hodge and Kress, 1988 & Kress and van Leeuwen, 1996). The field of social semiotics 'is primarily concerned with human semiosis as an inherently social phenomenon'; moreover, it is concerned with 'the full range of semiotic forms...semiotic texts and semiotic practices' (1988, p. 261). Work in the area of social

semiotics has increasingly viewed semiosis, the social production of systems of signs and meanings, as a 'multimodal' and 'multi-channel' phenomenon (Kress 1995, Lemke, 1998).

Our perspective is also informed by work in the fields of anthropology (Bateson, 1978; Geertz, 1993), social interaction (Goffman 1974 &1969; Kendon, 1990) and cultural psychology (Vygotsky 1994, 1986, 1978; Daniels 1996). From anthropology we wish to emphasise the importance of viewing localised social and cultural encounters and practices within wider patterns of social relations. These located encounters are simultaneously constitutive of, and are saturated with, the traces of wider social relations. Following on from this, we see the social interactionist perspective as reinforcing notions of the reciprocity and patterning of social encounters (there is also work being done at the meeting point between linguistics and interaction: e.g., see Ochs *et al*, 1996). Every action, every utterance, is made with the consciousness of other social actors, who watch, listen and respond (Voloshinov, 1973). The concept of *frame*, developed by Bateson (1978) and elaborated by Goffman (1974), allows us to observe and analyse the meaning of particular actions with reference to sets of contextual markers and patterns of social activity. These markers delineate particular episodes and sequences of activity. Finally, as we are concerned with learning, the development of mind in and through action, the cultural psychology developed by Vygotsky and his successors is important because it helps us to see meaningful socially patterned activity as the generative locus of consciousness (see also Voloshinov, 1973).

Ultimately, although the full range of description and analysis is beyond the scope of this particular paper, we are aiming towards a social, cultural and semiotic account of complex social activity, focusing on the ways that the physical actions of socially organised persons make meaning. The attempt is to make a three-dimensional account of action in classrooms, or, put another way, to work towards a fullness of 'multimodal' description and analysis referred to by Clifford Geertz (1993) (drawing on Gilbert Ryle) as 'thick description'.

In what follows we will use excerpts of a particular science lesson as our evidence to examine three aspects of action. First, focusing on the human body as material for making meaning, we look at

the ways in which pupils as groups of individuals make and reveal meaning through gesture, posture, 'face-work' and so forth. Second, we examine how pupils arrange themselves in relation to each other and objects in the science room, and how they move in and through space and time. Third, we examine how pupils interact with the materials, objects and equipment of the science classroom. Although it is clear that these aspects are inextricably linked, we are able to separate them out for analytical purposes because they are not reducible to each other.

Analysing action

In order to build up a detailed description of multimodal classroom interaction we viewed videotape of the lesson many times: with image only, with sound only, and with both sound and image. This data was supplemented by four other sources of data: observation notes made during the lesson; materials used in the lesson (e.g. text books, work sheets); texts produced by pupils and teacher; video and transcripts of focus groups with pupils. Through intensive group viewing of the data using the concept of frame we built a description of classroom interactions (the transcription process focused on all modes, action, speech, and visual). We produced a systematic account of action from descriptive dimensions highlighted as important in the literature: eye movement, direction and gaze; facial expression; hand and arm movement/configurations; the use of the whole body to make gestures; body posture; the position of people in the room and their use of space; the location and context of the action (e.g. the semiotics of architecture); and the semiotic objects of action (Bateson, 1978; Bitti and Poggi, 1991; Merleau-Ponty, 1969; Crowder, 1996). In this way we produced a 'thick descriptive' account of what we call multimodality—that is, how action, visual, and linguistic resources work together to make meanings. This account was analysed to generate semantically motivated descriptions of action, and to explore how action realised different semiotic meanings in the science classroom. We examined the patterns and structures of action, to *prise open meanings*, to understand the meaning structures and the ways these were combined to make meaning through action. The role of different semiotic objects in action was explored. We looked at action in relation to the other modes operating in the classroom. We examined the context of gesture to identify the functional meaning of gesture in relation to larger units of communication (e.g. did the action open up the dialogue, or manage the transition from one type of speech to

another?). Through the comparison of actions, modes, and contexts we identified repetitions, reiterations, structured patterns, and transformations of action. This allows us to view specific and located action as situated within the context of broader patterns of social activity.

The example discussed in this paper is drawn from a year nine (students aged fourteen years-old) science lesson on energy and concerns an investigation of what makes a good fuel. The investigation consisted of burning four types of fuel ('metafuel' tablets, paraffin, sawdust, and paper) to heat a small amount of water in a boiling tube in order to measure and record the highest temperature the water reached with each of the four sample fuels. The teacher stood at the front of the classroom and delivered a monologue, instructing the pupils how to conduct the investigation. Her monologue was punctuated with the action of displaying the semiotic objects (the clock, tripod, etc.) to be used in the investigation and served to 'translate' the visual and written worksheet into action and speech.

Insert figure 1: Worksheet

The teacher's expectation (ambiguously expressed but made explicit later in the lesson) was that the investigation should consist of two trials; that is, the process was to be repeated with each fuel. The teacher asked the pupils to work in groups of three or four and took a 'hands off' approach throughout the investigation.

The body

If we focus on action as a social rather than a biological phenomenon then we must understand the body—the material means of our action—as social. The social nature of the body, social attitudes, traditions, and techniques are assembled, transmitted, 'borrowed', through active imitation, and transformation. The expression of the body is shaped by the social order imposed by the environments and cultures we inhabit (Merleau-Ponty, 1969; Butler, 1990). Patterns of recursive bodily action in given contexts, reiterated and reinforced over time can be described as *habitus* (Mauss, 1979; Bourdieu, 1991). Following this, we suggest that the body, as the material and

vehicle of action, is fundamental to understanding the meaning of action. To stake the claim at its largest possible value, the human body is pre-eminently the main material for making meaning. Any given place in social and cultural life is given meaning by the presence, or potential presence (even in its absence, the body locates meaning) of human bodies, arranged in relation to other bodies. Although we focus predominantly on the body, we want to emphasise how patterns of physical action both give material substance to patterns of thought and, at the same time, how patterns of activity are internalised as modes of thought. This is to say that we see physical action and thinking to be reciprocally related and mutually constitutive.

Clearly, there are also social meanings that accrue to and valorise the body as a visible entity in terms, for example, of sex, colour, size, clothing and adornment. With or without action, these signal much about the status and group affiliation of social subjects. There is not space to deal adequately with these aspects of the 'body as sign' (for examples, see Franks 1996 & 1995). Nevertheless we should hold in mind that in the descriptions of pupils' activity that follow, especially in the roles which pupils take in group work and their concomitant actions and spatial arrangements, there are inscribed the personal, social and cultural histories of these individuals. These things signify aspects of their home backgrounds and their relative position within the peer group.

Viewing the body as the expression of meaning in this way, the process of action can be seen as 'bringing meaning into being' rather than translating meaning into action. In other words we see the body as a meaning-making resource: the body both produces signs and is itself a sign. The demeanour of the teacher's body when using a microscope, for example, can embody historical scientific traditions and knowledge, indicate respect for the equipment, show an understanding of the effect of light on the mirrors, and embody 'observation': here action represents *doing* and *being* a scientist. Pupils make sense of the science teacher's *habitus* through imitation, and transformation.

Remaining with the idea that the body is a fully articulated entity, and without wanting to dissect the body and atomise it into its constituent parts, we nevertheless want (for analytical purposes) to draw attention to the features and dimensions of the body and bodily movement that are particularly significant in looking for the meaning of bodily action. First, there are two concentric spheres of bodily action. The innermost sphere is the one described by the body's movement around its own axis. Then there is an outer sphere described by the body's movement through space. We examine this level of 'gross motor' activity through space more closely in the following section. Here we particularly concentrate on the upper third of the front of the body, although stance, position of the feet, swivel of the hips is also relevant. The meaningful features of the upper part of the body (and this is more general and indicative than it is an exhaustive list) include the inclination and orientation of the trunk, movement of the arms and (especially) gestures described by hands, the position and orientation of the head (especially the face), facial expressions, movement of the eyes and direction of the gaze. Clothing and accessories that we choose for bodily adornment also have significance (take, for example, that the teacher wears a white laboratory coat).

We can use a brief example from the year nine lesson, contrasting two groups of pupils as an illustration of our point. The excerpt of transcript reproduced below captures two of our main protagonists (A. and B.) as they set up an experiment on burning fuels. Not represented in the transcript, but within the video frame, we can see pupil C. in the background (later in the video, the camera angle is changed to concentrate on the group whose work is transcribed below and C. disappears from the frame). At 11.13, when the teacher has finished given instructions and worksheets have been distributed, we see A. in the foreground, standing by his place at the bench arranging the Bunsen burner, the tripod, gauze and clock. He takes the stand and fiddles with the wooden clamps that are there to hold the boiling tube and, above it, the thermometer that is to be dipped into the tube of water. His movements are deft and purposeful. His head is inclined downwards, concentrated on the equipment on the bench and his expression shows serious concentration. His gaze flicks between the worksheet and the equipment, checking that he has everything in the correct arrangement. In the background, we see C.. He remains seated and

pushes the Bunsen burner around the bench without apparent purpose. He constantly looks around him at pupils on either side, sometimes smiling, sometimes talking to other pupils.

By 11.14, C. picks up the plastic goggles from the bench in front of him and puts them on. He looks up, smiling, clearly trying to draw the attention of those around him. In contrast, A. has checked the worksheet again and takes the tripod and arranges it over the Bunsen. Having done this, he picks up his goggles and slips them on. In contrast to C.'s 'clowning', A.'s donning of the goggles is serious, safety conscious and businesslike action. Next, A. checks the worksheet again, moving it closer to the equipment before he moves the clock (with which, earlier, another pupil has been playing) and arranges it behind and to the right of the Bunsen and tripod. Here it can easily be read. He calls for B. to get a boiling tube and is still shifting his gaze between the equipment and the worksheet as B. arrives back with the tube. B. has to wave the tube to attract A.'s attention, swivelling it between his thumb and forefinger in front of the stand in the line of A.'s gaze. A. is standing directly in front of the assembled equipment, facing and gazing forward. B.'s interventions come from A.'s right side, with B.'s body orientated at an angle to the bench so that he has access both to the equipment and to A.'s face. He looks from the equipment towards A.. B. says something to A. about the arrangement of the clamps, which in his concentrated activity, he does not appear to absorb. B. then repeats the point, but this time with animated pointing gestures. This time, A. appears to grasp B.'s meaning. All this time, at the end of the bench, C. has remained in his seat, grinning and looking from side to side trying to gain attention from his classmates. C.'s actions in this instance are apparently motivated less by achievement in school science but are more about his position within the peer group.

In these two minutes, we witness how different loci of attention and interest are represented in the orientation of the bodies, gestures and direction of gaze of these two groups of pupils. These are precisely the sort of signals that teachers use to gauge the involvement of pupils. In the course of everyday school life, if teachers and researchers mark these signals in any way, they are most likely to be referred to as 'body language'. Our more schematic representation might help to provide a framework for more detailed description and analysis of action (even though, in our brief example,

we have only been able to develop a limited and indicative account). The pupils' specific histories combined with the ways they act in the classroom give us an indication of their motivational orientation within the discourse and activity structures of the classroom. Close analysis might provide a meaningful basis for comparison and contrast of learning activity. Here, we have been concerned to describe aspects of bodily communication as indicators of attention and involvement and we shall return to this later. In the description of B.'s 'analytical' gesture indicating the problem of the clamps, we approach a form of description and analysis in which we are looking for evidence of social learning processes.

Setting up the investigation: the boundaries of time and space

Time can be seen as a means of articulating rhythms, and relationships, while space articulates relations such as 'in front of', 'inside', 'outside'. Context, the social-cultural analogue of time and space, articulates long established relationships of patterns of action through history to patterns of activity in particular institutions, both on macro-level, in terms of the history of Western science, and on a micro-level in terms of the history of particular school science departments and so forth. Time and space can therefore be seen as dimensions or resources available to the meaning maker via the creation of patterned structures of action (e.g. rhythm and pace). Pupils and teachers move through the space of the classroom, position themselves in relation to one another and to the artefacts of science; that is, classroom interactions are located in a particular socially defined space and at a specific point in history. In short, time and space are distinct but inter-connected dimensions that articulate meanings and form a site of meaning making. Human social behaviour is, therefore, moulded by the cultural, social, and historical traditions in which it is produced—it is neither universal nor unique to individuals. The social use and arrangement of space (e.g. seating arrangements) in schools, in this case the science classroom, represents the petrified formalisation of pedagogic power relationships (Sutton, 1992).

Here is an excerpt of transcript that typically describes the setting up of the experiment (16 minutes).

Time Position	Action	Verbal
11.13	B.: left the bench and returned with a Bunsen burner, a heat mat, safety glasses, and a pair of tongs. He then left. A.: stood up, walked around the bench picked up the work sheet, placed the Bunsen burner on the mat. D.: left the table. returned with a tripod B.: returned with a heat mat. A.: put the Bunsen burner under the tripod and on top of the mat. B.: put the heat tray on the tripod. D.: left the bench B.: left the bench A.: moved the arrangement of equipment across the bench and connected the Bunsen	
11.14	burner to the gas outlet. B.: returned with a clamp-stand and left. A.: set up the clamp. D.: returned with the stop-clock and put it on the table.	A.: B., go and get a test tube. B., go and get a boiling tube.
11.15	A.: put on safety glasses looked at the work sheet and moved each piece of equipment he 'fine tuned' the set up. B.: leaves and returns with a boiling tube A. puts the boiling tube in the top clamp	
	B.: points at bottom clamp moves around him to help take it out and puts it in the bottom clamp B.: leaves the bench. A.: set up the clamp and gives the boiling tube to D.	B.: Put this one there Now we need something else to hold it there. A.: Here hold this.
11.16	D.: handed back the boiling tube. B.: returned with a thermometer handed it to D. who looked at it and then placed it on the bench near A.. A.: picked up the thermometer put it in top clamp. B.: stands next to A. and holds it A.: tightens the clamp.	

Although the pupils spoke during the task we suggest that their speech did not organise the total activity. In this instance, the construction of meaning depended on the combining process of action in which language was a ‘secondary’ form of action.

Insert Table I. The type of meaning function realised in the pupils’ action and speech

During the setting up of the investigation, the differing relations of the pupils within the group were realised through their spatial relationship to one another, their position in relation to the bench and the classroom, and their interaction with the equipment. And, as we noted above, their positions in space and their functional roles within the group are clearly influenced by their position within the peer group.

The activity which took place in the classroom was within the limitations and potentials for action afforded by the classroom setting in its layout, size and shape, as well as the spatial relationships 'mapped out' by the arrangement of the furniture (e.g. the pupils' benches, and the raised teaching bench at the front of the classroom). When working in small groups one person would necessarily be nearer the equipment, and others more peripheral to the investigation. Each group of pupils would be relatively isolated from the other groups.

In the setting-up the equipment, A. was the central 'co-ordinator of the activity' in the group. He did not move around the table until the equipment arrived. He rarely left the table to collect equipment. In contrast B. left and returned a total of 16 times. He placed each piece of equipment in position. He decided on the positioning of the equipment on the bench and occupied the central position in that space.

In connecting the equipment, A. constructed the material 'frame' for the investigation (Bateson, 1978). He measured the water. He checked and counted the fuels. He drew the table for the results to be entered into (which the rest of the group later copied). A.'s central role within the investigation was realised and reinforced in relation to other members of the group and the equipment through the rhythm of his actions.

The repetition of the pupils' actions throughout each phase of the trial produced a contrast in time and space, a rhythm, which itself realised meaning. Each of the phases of the trial with each sample fuel took a different length of time and was performed with varying degrees of ease. The rhythm of the pupils' action developed forms of contrast and comparison through time and this contributed to

the construction of ‘fact’. The textual structure of the results table was the ‘mediating device’ that enabled the transformation of the pupils’ repetitive actions (for the burning of each fuel) into comparisons of the characteristics of the fuels.

The pupils’ articulation of space through their repeated movements realised their relationship to the process of doing of science. We can gain some measure of the pupils’ involvement in the lesson if we take the equipment as the focus of attention. By drawing a notional circle one-meter in diameter, using the equipment as the centre, we can get an indication of pupils’ differing levels of involvement by observing the frequency and duration of time spent within this ‘circle of attention’. A. took a central position within this space of involvement, establishing himself in the role of the central investigator by connecting the equipment together. B. moved in and out of a near-central role: his centrality was located in his movement through the classroom to collect equipment. D. and E. remained primarily on the edges of the investigation—literally hovering on the margins. They entered the physical domain of the investigation to pass objects when it was vacated by A. or B., but primarily their role was as observers. Their positioning in space, their relative proximity to each other and to the equipment, established, materialised and reinforced their relation to each other in the ‘doing of science’. The pupils’ roles and use of space worked to realise the collaborative yet hierarchical nature of science.

The pupils’ movements in time and space can be seen as the realisation of the effect of science as a sequence of incremental actions and as a neat arrangement in space—the activity of doing science. In setting up of the equipment the pupils worked to (re)produce the image on the worksheet with the resources available to them. Through action they ‘re-drew’ the worksheet as a three dimensional physical entity. The image functioned as an anchor and a spatial template for the task and the pupils’ actions. When A. looked at the worksheet and then realigned all the equipment, he appeared to be attempting to reproduce the general effect, including the affective dimensions of ‘being a scientist’, as well as the spatial relationships represented in the image.

The pupils' actions, their movement through space and time, was the dominant semiotic mode in setting-up the investigation. Their speech served to confirm the roles of pupils in the group. A., for example, spoke more than the other pupils, gave instructions and conferred with the teacher, while B. responded and monitored what was needed to enable the action to proceed. As summarised in Table I, the pupils' action and speech realised different meanings and had different functional specialisms. On an interpersonal level, the pupils' actions realised their different roles in the task (as collectors, connectors, and observers), their centrality to the task of doing science, and their position in the hierarchy of the group within the science classroom. Their actions also realised ideational meanings through the collaborative construction of the material structure of the investigation: the arena of events to come. The arena of the investigation was not 'ready-made'; it was an assembled system, built up from ready-made parts. Through their actions the pupils first identified and selected the resources, then connected the different parts in order to construct the equipment for the experiment. Located within the patterns of activity of doing science, they expected this equipment to be the tool that would enable them to generate new (scientific) meanings in the subsequent course of action. Pupils also corrected one another via action rather than speech —that is their actions served to realise the norms, order, and structures of doing science.

Entities, and objects which mediate action

The meaning of the objects and entities which mediate the learning of school science is materialised in our interactions with them in the science classroom and elsewhere. Meaning accrues to the objects themselves through human interaction with them through history. Objects in the science classroom are framed by the science lesson and made suitable objects of scientific thought and experimentation through the activity of the teacher and pupils. In this process an object acquires a new (if temporary and context bound) 'form of existence' and new significance in the science classroom. The action involved in working with objects in science lessons transforms objects so that they come to mean more than their immanent materiality (see Bakhurst, writing on Ilyenkov and Vygotsky, in Cole et al (eds), 1997). We suggest, therefore, that scientific equipment shape the potential for meaning in the science classroom. Interactions with such equipment fashions

meanings, which in turn conventionalises objects and promotes them into scientific routines or 'ritualised' actions.

During the setting up of the investigation described in the previous section of this paper, the pupils used the equipment made available in the classroom in their attempts to reproduce the image of 'setting up' produced in the worksheet.

> The pupils collected together the remaining equipment and sample fuels. The wooden clamp stand was exchanged for a metal one. A. experienced considerable difficulty in fixing the clamps to the clamp stand as they were not compatible. Different clamps were fetched and tried. Eventually, A. left the bench to collect the exercise books and draw up a results table. B. left to look for new clamps. Meanwhile E. and D. attempted to construct the equipment for the experiment. B. returned with another clamp and he and D. tried alternative ways of holding the thermometer. A. then returned to the task of setting up the equipment, demanded B. find another clamp. B. returned with the correct clamp and together they set up the stand.

There was a shortage of the correct clamps, and a collection of incompatible clamps had been set out for use by the pupils. Two of the pupils in the group (E. and D.) used the incompatible clamps and in doing so became engaged in an attempt to transform the 'set-up' of the investigation, creating an alternative workable version. Their efforts focused on how to hold the thermometer in place (an aspect of the set up which was not explicit in the worksheet). As a result, the process of setting-up the investigation was constrained by the tools—the incompatible clamps—selected for the experiment. The clamps, tools of experimentation, mediated the pupils' experience of the lesson. Their actions realised science as a structured and systematic process that could not be transformed.

The pupils' actions with the equipment contributed differently to the classroom process of making 'convincing', or legitimate, knowledge. A. and B. became part of the experiment through their handling of the equipment: they became 'proficient learners'. Their actions confirmed the learning value of experimentation in school science. In contrast, E. and D. did not possess a viable tool (the correct clamp and a visual anchor within the worksheet) to mediate their action: their actions confirmed their lack of expertise in the science classroom. The equipment itself both imposed certain material limitations on, and afforded various potentials for action and interaction with it. It was the mediating tool, or pivot, for the pupils' understanding of science in this particular lesson.

At the same time, the equipment mediated the pupils' different expressions of 'becoming' scientific selves.

The next stage of the investigation, the first trial of burning the four samples of fuels, emphasises the role of objects mediating action and the functional specialisation of different modes. In this example we suggest that different meanings were realised through the pupils' action and speech: here action is the main stuff of meaning, speech is a commentary on the detail of the action. The pupils' actions with the equipment functioned to construct fact through empirical evidence. A typical excerpt of the first trial, the burning of a sample of metafuel, is transcribed below.

Time	Position	Action	Verbal
11.31		B.: lights fuel with Bunsen	
		A.: picks up clock and sets it	
		A.: holds hands together as if holding fuel with tongs	A: Am I supposed to keep on holding it like that?
			B.: No I don't think so
		A: leaves bench	A: I'm going to go and ask miss
		D.: picks up worksheet and reads	T: No once it's lit than that's all right
			B.: See!
		A.: returns, lowers bottom clamp	A.: Make it a bit more lower
		E.: points with his glasses at the experiment	E.: Check the temperature
			D.: It's about 30
		A.: points at B.	A.: Keep an eye on the temperature
		all look at equipment	
		B.: looks at thermometer	B.: It's going up,
		raises his fist	31 yeah, 3b, 39, 41,
11.32		starts to dance	50, 51, 52
		A.: checks clock	A.: Going to hold it for three minutes
		B.: puts his glasses on, leans in	B.: 61, 2, 3, 4, 5
		A.: gets exercise book	A.: I'll write the results down yeah?
			B.: Okay
		points at table	A: Am I supposed to tick it? Name of sample tested. What's the sample? looks at B.
			B.: Thingy, energy cube
		A.: leaves table	A.: Miss?
			A.: Tablet solid
			E.: Fuel solid
		D.: brings back box and gives it to A.	
			A.: Metafuel they call it
			B.: No solid fuel tablet
			A.: Metafuel
		T.: arrives holds box, reads	T.: Metafuel
11.33		A.: writes, reads table	A: Easy to ignite?
		looks at experiment, writes	B.: Yes
		reads table in exercise book	A.: Does it keep burning? Yeah
		bends down and looks at experiment	Is there smoke?
		looks at B.	B.: Can you see any smoke?
		writes	B.: No there's only a flame

	looks at equipment	
	B.: puts splint in flame	A.: B. leave it, B. leave it
	picks up clock	A.: Oh we leave it for 4 minutes. Oh it's quite burning now. It's nearly 3 minutes. We're supposed to leave it burning now till it stops
11.34	B.: walks around looks, takes glasses off, looks at thermometer	
	All lean forward and look	B.: What is it? What is it?
	D.: looks at thermometer	D.: It's over one hundred
		E.: Leave it
		A.: Leave it until it stops burning
	All leaning forward looking	B.: See how long it takes init?

As Table II suggests action and language were equally dominant in the meaning making process detailed above but had different functions.

Insert Table II: Type of meaning function realised by action and speech

Pupils' interests and motivations were key aspects in their actions which were mediated by their use of the different resources (e.g. the worksheet, and the equipment) available to them in the lesson. For example, A.'s interests informed his actions in response to the construction of 'what to do' in the worksheet which stipulated the arrangement of the equipment, the process of repetition, and the orchestration of the action. The worksheet (Figure 1) included three images all of which had a strong diagonal vector acting on the fuel sample (a vector determines the point of one position in space relative to another: see Kress & Van Leeuwen, 1996). The vector in the first image is formed by a Bunsen burner, in the second it is formed by a pipette, and in the third it is formed by a lit splint. A. attempted to 'translate' the action of the visual vectors through his action. He held his hands together as if holding the fuel in the tongs, pointed diagonally at the Bunsen burner, 'Am I supposed to keep on holding it like that?' Through this action, A. 'filled in' the human actors absent in the worksheet image.

The example table in the worksheet is an example of how the resources made available by the teacher in the lesson mediated the activity of the pupils and how these were transformed by the pupils' interests. The results table in the worksheet set the criteria for 'what is a good fuel' and

provided a template for the pupils. A. copied the example table on the work sheet into his exercise book. In the extract shown above he used the table in order to understand what data was to be collected. Throughout, the pupils within the group appeared to be confused about how the end of the experiment was signified: was it when the water boiled or reached its highest temperature, or when the fuel burnt out? The teacher's declarative, 'Its boiling you've finished...' confirmed that (at least in her view) it was the former. However, A. transformed his results table, adding a column for time—indicating that, at least for him, the end was *also* when the fuel burnt out. This transformation enabled his interest in 'what makes a good fuel' to be incorporated. In so doing, the purpose of the investigation was transformed, and higher value was ascribed to the measurement of time over the measurement of temperature (which we suggest could be a more valid everyday criterion for A. in thinking about what makes a good fuel).

The pupils' interaction with the equipment and objects in the science classroom realised the construction of fact through empirical evidence, measurement, and classification. The thermometer transformed the concept of heat into a quantifiable thing—a rise in the fluid in a thermometer. In this way the factual evidence was made convincing through the measurement of a visible material response. 'Convincing' scientific truth, defined as an evidential act, was achieved through the description of a visible, quantifiable, measurement of 'reality'.

Conclusion

The framework presented and exemplified in this paper offers a way to address the social aspects of meaning making applicable to education, in particular the ways in which pupils make and re-make signs across communicative modes in their process of learning. We have shown how the teacher and pupils made meaning through their position in the classroom, their body posture, movement, and their interaction with resources in the classroom.

In particular, our analysis of action demonstrates that action communicates meaning and shapes interaction in the classroom in many different ways. Action in the science classroom can bring entities into existence, imbue them with certain qualities and confer agency. It can challenge our

conceptions of the world, and provide us with resources to imagine and think with. Action can make ideas seem real, create involvement, construct fact, and convey the realism of scientific truth. It can realise different expressions of self as learner or teacher, and connect the worlds of science and the everyday in concrete ways to make new meanings. It can convey social responsibilities, express historical meanings and the experiences of science. Through action, something can be made to seem central, authoritative or peripheral to the rhetorical task at hand. It can realise and enforce inter-personal relationships within the classroom. Action realises the value of the *doing of science as a process* and situates specific actions in particular lessons within the patterned activity of doing science in the world. Action in the activity system of a science lesson has conventionalised forms, such as demonstration and experiment. We have shown that action using the tools of an activity system is a way of making meaning.

Focusing on the meaning of action within the science classroom draws attention to important aspects of learning that attention to language alone does not. In particular, the ways in which the experience of being a learner is mediated through interactions between people, objects, equipment and materials within the science classroom. Drawing attention to how these interactions mediate success or failure focuses attention on the key role of the teacher in establishing and orchestrating successful interactions within the classroom. The analytical approach developed here draws attention to aspects of action which do not need exhaustive description and analysis, but emerge over time as a patterned and reiterative mode of making meaning.

This analysis of science classroom interaction demonstrates that action is not simply an illustration of language, rather that action and speech do different things, and they realise different meanings in the multimodal environment of the science classroom. In other words, action and speech have different *functional specialisms*. Each mode has different meaning potentials and limitations, and perhaps more importantly the different functional specialisms each mode realises makes different demands on the audience. The shift between modes in the classroom represents a shift in the mental possibilities and demands on the learner both in intellectual and affective terms. In this way action,

gesture, image, and speech interweave to rhetorically make meaning; to shape pupils' views of the world in complex ways which language alone cannot realise.

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Table I: The type of meaning function realised in the pupils' action and speech

Setting up investigation	Mode	
Type of meaning function realised	Action	Speech
Interpersonal	Roles in group (connector or collector) Dialogue - hierarchy Correction	Roles in group Monitoring
Ideational	Identification of resources, the connection of parts to make new things - realise new potentials - new meaning structures (arena) for action to happen in, attention to detail and order Marks the concepts of time, and measurement	Identify gaps in equipment set up to enable action to proceed
Textual	Establishes patterns of meaning in science process. Rhythm, repetition	Marks key points in process

Table II: Type of meaning function realised by action and speech

Trial One	Mode	
Type of meaning function realised	Action	Verbal
interpersonal	we are ready roles in group establish authority involvement excitement control attention	teachers authority roles in group
ideational	indicate object of interest process of observation measurement preparation mediates definition dialogue of verification emphasises area of negotiation (e.g. holds clock when neg. time) introduces alternative agendas - pupils interests	refinement of actions results of measurement classification definition negotiation instruction
textual	establishes patterns of meaning in science process: observe, measure, record	confirms patterns of meaning reinforces rhythms over time—opening, process, closure of experiment

Figure I: **Worksheet**