

Exploring Learning Through Visual, Actional and Linguistic Communication: the multimodal environment of a science classroom

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ABSTRACT *This paper draws on ideas and data from the ESRC funded research 'Rhetorics of the science classroom: a multimodal approach'. It suggests that learning is realised through the interaction between visual, actional and linguistic communication (i.e. learning is multimodal) and involves the transformation of information across different communicative systems ('modes'), e.g. from speech to image. It demonstrates that learning is a process of selection, adaptation and transformation motivated by the interests of pupils and the context of learning. Specifically, it analyses the different ways four Year 7 science pupils transformed their teacher's descriptions of cells in their production of texts on onion cells (and the choices they engaged with in producing them), focusing in particular on their use of analogy.*

Introduction

Previous educational research has tended to focus on classroom talk and written texts, reflecting the dominant view of learning as a primarily linguistic accomplishment. In contrast, our research has explored the full repertoire of meaning-making resources which pupils and teachers brought to the classroom (actional, visual and linguistic resources) and how these were 'organised' to make meaning, i.e. we took a 'multimodal' approach to classroom interaction (Kress *et al.*, 2001) [1]. Extending communication to refer to all meaning-making systems, what we term 'mode' (organised, regular, socially specific means of representation), including language as speech or as writing, highlights the need to consider how teachers and learners use a range of modes to express meanings in the classroom. A multimodal perspective, as this paper will demonstrate, brings visual expressions of learning into focus and enables research to 'recognise' the central role of action in the learning of science. This paper tentatively concludes that a multimodal perspective offers some new messages for the practice of science teaching.

Learning as a Process of ‘Sign Making’

We view learning as a process in which pupils are involved in actively ‘remaking’ the information and messages (or complexes of ‘signs’) which teachers communicate in the classroom. In this way learning can be seen as the pupils’ ‘reshaping’ of meaning (‘signs’) to create new meanings (‘signs’). This conception of learning as *a dynamic process of sign making* is informed by social semiotics (Halliday, 1985). The field of social semiotics is primarily concerned with communication as an inherently social phenomenon (Hodge & Kress, 1988). The conceptual framework of social semiotics accounts for how modes of communication (speech, writing, image, gesture, three-dimensional models, etc.) are used. This account is based on the assumption that communicative systems have evolved to satisfy societal needs and that modes such as writing or gesture are organised to function with respect to these needs, e.g. language, in Michael Halliday’s phrase, is as it is because of its social uses.

The organising concept of a social semiotic approach is that meaning *arises as a consequence of choice* and that meaning is multiple. So, for instance, if I dress formally rather than informally when meeting someone, I make a choice and that choice expresses a meaning I wish to make about that meeting. When we make meaning we have and exercise choices in simultaneously constructing a presentation of something, orienting it to others and in doing so we create an organised structure of related elements (Lemke, 1998). In formal ‘grammars’ these three types of meaning functions are modelled as sets of features which represent the work which is required (the choices available) when encoding or decoding a text. In the innocuous greeting ‘lovely day we’re having’ I am presenting information in a fashion relevant for my neighbour, in an utterance that fits unobtrusively into its particular environment.

Recently, this approach has been elaborated to take account of modes and systems of making meaning other than language, including music/sound (van Leeuwen, 1999), action (Martinec, 1996), visual communication (Kress & van Leeuwen, 1996; O’Toole, 1994). Most recently, work in Hallidayan functional linguistics (Martin & Veel, 1998) and in social semiotics has increasingly viewed the social production of systems of signs and meanings as a ‘multimodal’ phenomenon, i.e. there is now an increasing understanding that occasions of communication always draw on a multiplicity of modes of communication at the same time. When we speak we also make facial expressions, we gesture, stand at a certain distance and so on, all of which make meaning together. This ensemble of modes we regard as the normal condition of communication and we refer to that as multimodal communication or as multimodality.

Within this theoretical perspective we can look newly at what happens in classrooms. Importantly, pupils’ remaking of a teacher’s message to create new signs can be seen as the process of learning. We regard what the teacher says or does as a complex of ‘signs’: a meaningful complex of form and content seen as a motivated whole. This ensemble of communicative actions constitutes many of the resources (and imposes some of the constraints) involved in pupils’ production of texts in the classroom. These representational resources are, to some extent, also constrained by ‘how the world is’, i.e. phenomena, objects and events in the world, as well as the teacher, play an important role in mediating the meanings that learners produce. That is, from the complex of signs, made in a number of modes, the pupils make their

selections, reflecting their 'interest' in the complex message produced by the teacher. Their selection is integrated into existing 'internal complexes' and forms the basis for their making of new texts. In this way, pupils' texts can be read as 'signs' which mediate their responses to the teacher's message: one kind of evidence of what thinking may have been like, i.e. we see learning as a motivated activity in which the interest of the pupil is expressed through their making of apt new signs in a given context (Kress, 1997). We analyse pupils' responses in terms of the new signs (new meanings) they are making out of the meanings made by teachers' texts utilised in the classroom, i.e. we treat teacher and pupils on a par, both producing new signs in response to the signs of the other, reflecting their different interests.

Approaching sign making as inherently involved in the dynamic process of learning, as a complex process in which teachers shape ideas to be learned through a plurality of communicative means (linguistic, visual, through the materiality of three-dimensional models, and through actional modes) in order to make these ideas appropriate and convincing to pupils, 're-opens' the question of why pupils' texts vary so much from each other. Today, viewing the learning process as the transmission of knowledge from teacher to pupil is less dominant amongst educational practitioners and researchers. Yet despite this, the common response to differences between pupils' texts is taken as an indication of pupils' failure to correctly read (or reproduce) the stable messages encoded in teacher's communications and is underpinned by this conception of learning. In contrast, we suggest that an alternative way of understanding the variation between pupils' texts is to read 'variation' as the pupils' shaping of meaning in what is for them the most apt and plausible way, reflecting their interests, with the resources available to them in a specific context.

The focus of this paper is how pupils transform the structural and content aspects of a teacher's communication through their use of a range of modes, their selection and adaptation of elements presented and their introduction of new elements. In other words, the focus is on how pupils use the resources made available to them in the classroom, from the teacher and from other sources (e.g. other lessons, from the television, their experiences and interests outside school) to construct meanings.

The analysis presented in this paper is based on: (1) observing the pupils' production of the texts; (2) interviews with the pupils about their experience of conducting the investigation and producing the texts; (3) the texts themselves. In order to 'get at' the cognitive processes of pupils' learning we focus on the texts as an 'outcome' of this process (in the form of 'complexes of signs'). We suggest that pupils' texts can be viewed as 'one kind of evidence' of the cognitive processes that they have engaged in: the effect of the teacher's communication at that particular moment on individual pupils. We analyse pupils' texts in terms of 'what is there'. This requires a rigorous and serious look at what pupils have actually produced: as writing, looking at the genres apparent in the writing; as image, the use of colour, the kinds of realism deployed in the images; in the combination of all these together. We take 'what is there' to be 'there' as the consequence of choices made by the pupil from among the resources made available by the teacher in preceding teaching, but also resources taken from talk with friends in class, from other experiences in school and from experiences and 'knowledge' out of school, aspects explored in the interviews with the pupils. 'What is there' is therefore a selection, a reconfiguration, a reshaping, the result of an active, complex process of transformation. In addition, we pay attention to the consequences, possibilities and limitations of the representa-

tional ‘design’ of the new text, to its rhetorical arrangement of mode and elements, as an expression of the intentions of the pupil as rhetor.

The purpose of analysing pupils’ texts as the product of the action of ‘making a new meaning’ is not to declare them to be correct or legitimate, incorrect or illegitimate, rather it is to explore the significance in the characteristics of pupils’ transformative actions.

Multimodal Learning

The lesson discussed in this paper centred on looking at the cells of an onion under the microscope. The pupils’ produced a text which recorded visually ‘what they saw’ and in written form ‘what they did’. The resources made available to the pupils to do this included: the teacher’s talk, in particular his use of two analogies for cells ‘a building block’ and ‘a honeycomb’ which served as a ‘template’ for the pupils’ transformations; worksheets to help them in their task, which also served as models of scientific texts; the materials and equipment for the experiment (microscope, slides and onions); the pupils’ talk with one another around the microscope as they engaged with the task.

At the beginning of the lesson the teacher stood in front of the pupils and exhibited the scalpel, slide, iodine and microscope required to transform an ordinary everyday thing, an onion, into an extraordinary unknown thing, a collection of cells. He described through pantomime action, manipulation of the microscope and his speech the process of the experiment. In summary, he performed the placing of a section of the onion skin on a slide, he pantomimed adding iodine to stain the cells, he acted out covering the slide with another slide cover, he pantomimed placing it under the microscope, he mimed adjusting the microscope and again through mime he performed ‘looking through the lenses’ of the microscope. His careful handling of the microscope and his naming of its parts, together with his comments on the great cost of the equipment, served to provide it with authority and to separate it from the microscopes they might have at home (‘this is not from Toys R Us’). The teacher’s demonstration of the process of the experiment also gave authoritative meaning to the process.

The demeanour of the teacher’s body, of what Bourdieu termed *habitus* (Bourdieu, 1991), when using the microscope embodied scientific historical traditions and knowledge, indicated respect for the equipment, showed an understanding of the effect of light on the mirrors and embodied ‘observation’: doing ‘being a scientist’. The pupils made their sense of the science teacher’s *habitus* through imitation and transformation.

The experiment involved the pupils and teacher in interacting with both everyday and scientific objects. Experiment realised the rhetorical function of constructing science as exploration and constructing the pupils as ‘scientists’ through handling of the equipment (e.g. microscope): the *habitus* of science. Experiment also rhetorically transformed the everyday into the realm of the scientific (e.g. the transformation of ‘onion’ into ‘collection of cells’). Experiment was used to construct the entity ‘cell’ through empirical evidence and the rhetorical stance ‘see/do it for yourself’. In this way experiment realised and construed a realist approach to the nature of science.

During the lesson the teacher gave direct instructions on three areas of making the text: composition and labelling; standard ways of drawing in science; ways of reporting an experiment. He requested the pupils to divide the page in their exercise

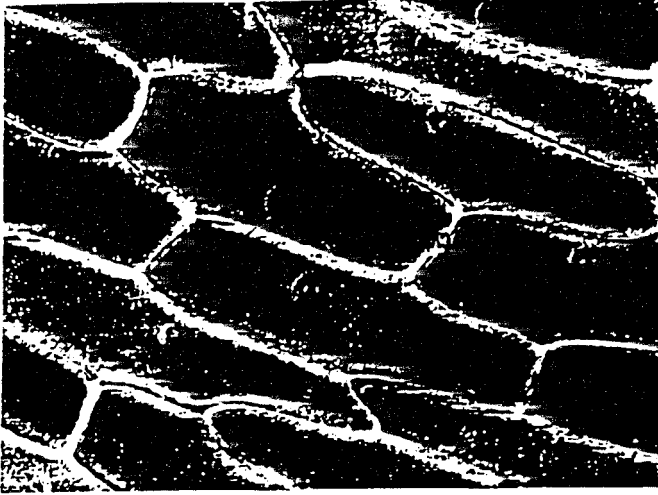


FIG. 1. The overhead projector image used by the teacher.

books into two halves and to draw the image of the onion cells in the bottom half of the page and later to write 'what I did' in the top half of the page. The relationship of the image to the writing as set out in the teacher's instructions suggests that he intended the image to be read as the actualisation of the writing: the result of the experiment. The switch in mode from image to writing served to further mark a clear boundary between the events of 'seeing' and 'doing', i.e. the compositional structure encoded process and result as two discrete categories. When the teacher's instructions on composition were followed the chronological order of the pupils' creation of the texts was reversed (i.e. first they drew and then they wrote) but the temporal order of action in the lesson was reflected.

The teacher introduced the pupils to the generic conventions of producing scientific drawings, namely line pencil drawings without the use of colour and drawing from direct observation. The teacher showed the pupils a photocopy of a generalised image of the pattern of onion cells magnified $400\times$ (Fig. 1) on the overhead projector to confirm what the pupils should look for and reproduce. The darkness of the photocopy obliterated much of the detail and reduced the detail of the representation of the pattern made by the interconnecting cell walls. This image functioned to highlight what the teacher wanted the pupils to look at: the pattern of the cells.

The four pupils who produced Texts 1–4 (Figs 2–5) participated in the same lesson: they had the same materials to work with. Yet, as a quick look at the texts shows, they produced four distinctly different texts. The setting up of a slide containing onion cells is a skill that needs to be developed and it is doubtful that year 7 pupils doing it for the first time will be easily able to produce one without air bubbles or multilayers of cells, it has, therefore been suggested that these differences are due to the fact that what they are looking at may be markedly different. It has also been suggested that these differences are the result of individual readings of the events in the lesson, a consequence of the pupils' lack of attention or their poor writing and drawing skills. Whilst these explanations may go some way to explain some of the differences between the texts we suggest that they do not provide a

convincing explanation of the pupils' production of such distinctly different texts (particularly as Texts 1 and 2 were produced by two pupils looking at the same slide through the same microscope). An alternative explanation for the differences between the texts, we suggest, is to see them as expressions of the different interests of the pupils and their transformation of the resources made available to them via the teacher. Transformations, for example, of layout and composition, representation (i.e. standard ways of drawing in science) and genres of reporting (expressions of 'scientificness').

In the following section we analyse the ways four of the pupils in the lesson transformed their teacher's descriptions of cells in their texts on onion cells (and the choices they engaged with in producing them). Specifically, we focus on the pupils' transformation of the teacher's analogies for cells in order to explore the role of multimodality in the process of learning, show the transduction of information across modes within learning and suggest that this multimodal transformation maybe motivated by the interests of pupils. The act of analysis within our approach is itself a reading of signs (even when supported by interviews with the makers of those signs) and we acknowledge that our interests and experiences are present in our analysis. We agree with the comments of Hodge and Kress in *Social Semiotics*:

The interpretation of texts is always a matter of guesses, not facts. But some guesses are richer and/or more plausible than others. A transformational reading of a text is often hypothetical to some extent, but this is by no means a reason why semioticians should avoid attempting it. (Hodge & Kress, 1988, p. 168)

Pupils' Texts as Transformations

The teacher introduced the notion of cells using the verbal metaphor 'building blocks'. The metaphor of cells as 'building blocks' enabled the pupils to begin to visualise the physical characteristics and properties of something usually invisible to them, building blocks. Building blocks, and therefore perhaps cells, are rectangular and have clear boundaries; probably they combine with each other to make bigger parts, to make a whole. The teacher used the analogy 'a honeycomb arrangement' to guide the pupils' experience of looking through the microscope at the onion cells, to help them see 'what you are actually looking for'. The teacher's analogy and later use of images (see Fig. 1) provided the pupils with an 'image' of what to look for before they saw the cells through the microscope, a pattern to act as a filter between their eyes and the slide with the onion epidermis.

This filter served to let the pupils know what it was that the teacher wanted them to record. Potentially, this raised a difficulty for pupils; what if what they saw did not look like what the teacher wanted them to see? What should they draw? The tension between the rhetorical positioning of pupils in relation to the experiment as revealing 'bedrock reality' and involving personal experience created a gap between teacher expectation and pupils' experience. *It is in these gaps that variation grows.*

Below we focus on two of the analogies used by the pupils, 'a brick wall' and 'a wavy weave', and how these analogies constructed the entity 'cell' in ways which transformed the teacher's meaning and extended their learning.

It Looks Like a Brick Wall

As Pupil A looked through the microscope in the lesson she said: 'it looks like a brick wall'. This analogy is also apparent in her drawing of cells (see Fig. 2).

She applied the analogy of a brick wall which was directly suggested in the worksheet and implied in the teacher's verbal analogy with building blocks and reproduced it by analogy in a different mode (image), i.e. Pupil A selected the rhetorical device used by the teacher and transformed it from a verbal to a visual analogy. Her visual analogy focused on the positive elements of regularity and uniformity of cells and visually embodied the relationship of the part (the cell or brick) to the whole (the onion or the brick wall). A brick wall is a familiar thing in an urban environment and the familiarity implied by the pupil's analogy comments on its everydayness: cells are everywhere.

Pupil A and Pupil B worked together in the lesson and they are friends. They looked at the same piece of onion through the same microscope. However, the comparison of their drawings (see Figs 2 and 3) shows that they are markedly different.

The strict rectangular shape of bricks is treated as a negative element of the analogy and ignored by pupil B in her image, while pupil A treated it as a positive element and included it (including the horizontal orientation of bricks) in the construction of her image. Pupils A and B incorporate the notion of irregularity in their texts, for instance Pupil B says: 'This is different it's got like cracks in it'. Cement and cracks in a brick wall are irregularities in an otherwise set pattern and the pupils' elaboration of the brick wall analogy in this way enables the analogy to account for the air bubbles in their images and in doing so marks them as irregularities. The possibility of irregularity enables Pupil B to share the brick wall analogy as she can now use it to explain the irregularity she observed. The analogy of the brick wall was selected and adapted to dry stone wall by Pupil C. Again, we suggest that the use of analogy by Pupil C is apparent in her image (see Fig. 4).

Here Pupil C transforms the context of the analogy from London to the countryside. She substitutes a commonplace wall in urban London for a rare type of wall in the countryside. If, as we suggested earlier, all signs are motivated, in other words the pupil chose to represent and describe cells as 'like a dry stone wall' as opposed to a brick wall or a wavy weave, what are we to make of her selection? We suggest, that the change in context and specification by Pupil C provides a more elite and distanced reference to cells (to those living in an urban environment). We speculate that her use of analogy suggests cells are well out of most pupils' everyday experience: you must have a specialist knowledge to be able to see them, you have to travel (metaphorically) to view it, it is outside the common urban experience: it is exotic. The context of the dry stone wall analogy, the countryside and the substitution of manufactured bricks with naturally formed stones suggests a link between cells and nature and introduced a sense of dynamism and potential for change through decay.

In summary, Pupil A's original analogy for a cell of a brick wall suggests the qualities of regularity, uniformity and structure, which are positive properties of the verbal analogy introduced by the teacher and transformed into a visual analogy. Pupils A and B incorporated the possibility of irregularity and the analogy was adapted further by Pupil C to introduce the notion of nature and specialism. The extension of the analogy happened through exploration of the neutral elements of

Looking at onion cells 26/11/99



What was the magnification?
Can you label any of the parts?

26 November 1999

Looking at cells

What I did ✓

At first Amanda and I collect all the equipment. Amanda peeled the skin off the onion, while I got the microscope. Amanda put the onion skin on the slide, then I put a drop of iodine on the onion then we put a cover slip on top of it. We then sorted the microscope out there.

We put the slide underneath on the stage.

We then looked in the eyepiece. It was an interesting experience to look at and draw. ✓
draw

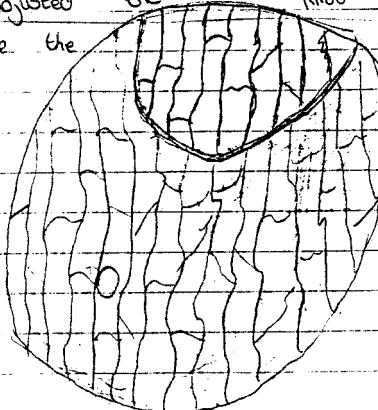
Good, but make sure you copy -
no missed work.

FIG. 2. Pupil A's text.

Looking at Onion Cells

16/11/97

What I did:
 First of all, Ramandeep got a microscope. I peeled some skin off of an onion and put it on a slide. Ramandeep put some iodine on it, and then put a cover slip on top. We put the slide under the microscope. Then we adjusted the knob until we could see the cells clearly.



Well done.
 Can you label up any of the parts?

FIG. 3. Pupil B's text.

analogy, which were finally treated as positive features and facilitated a better fit between the analogy brick walls and cells.

More Like a Wavy Weave

Another analogy introduced and used by pupils was that of a 'wavy weave'. This verbal analogy used by Pupil D is present in her visual realisation of the cells (see Fig. 5).

The analogy of a cell with a wavy weave again draws on the qualities of regularity and uniformity and presents cells as a part of something bigger, something visible. However, the scale of the analogy introduces something else; it presents cells as something less immediately visible than a brick; cells are not an obvious part of something. Pupil D's wavy weave analogy (and the other analogies she generated during our interview with her, 'a cotton weave like a sheet', 'like skin') conceives of cells as organic and dynamic in comparison with Pupil A's static analogy of cells

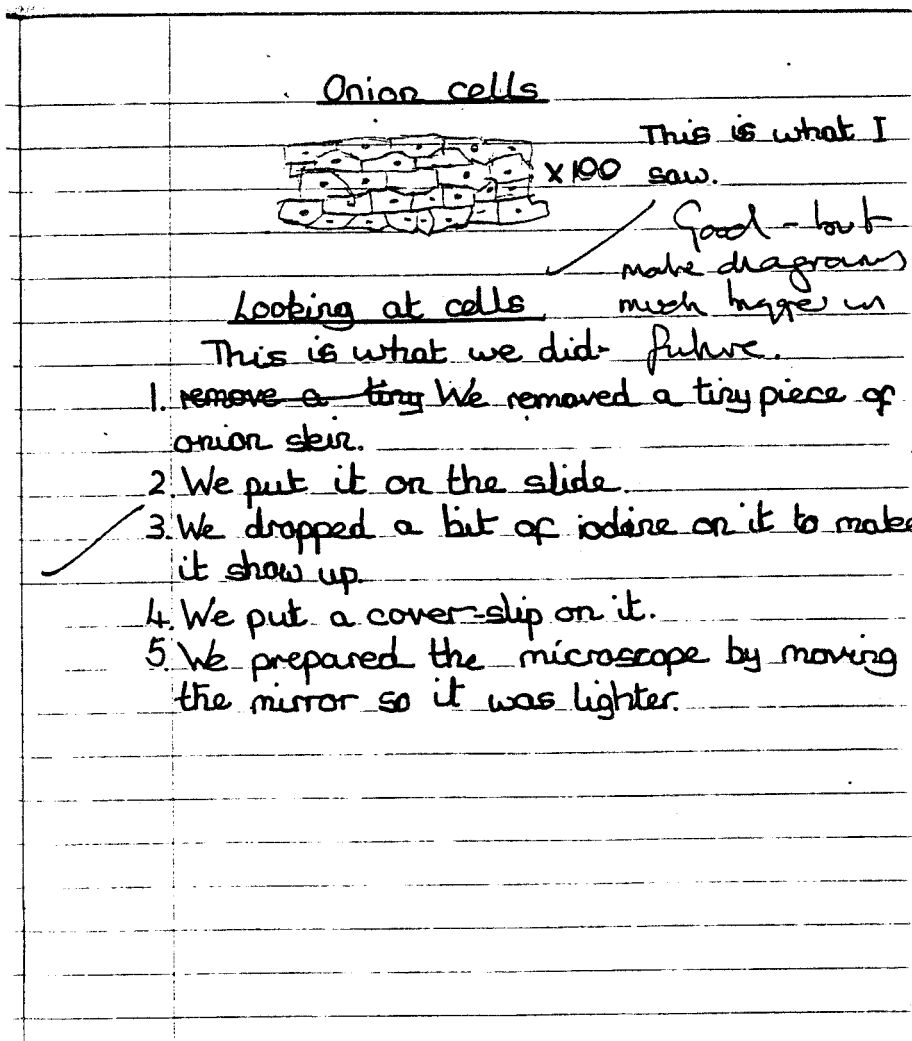


FIG. 4. Pupil C's text.

as bricks. This difference is highlighted by comparison of the lines of the drawing in Fig. 5, which are noticeably thinner and more fluid, with those in Fig. 2. We suggest that the construction of the wavy weave analogy is that it is related to the image of cells shown in the overhead projector by the teacher (see Fig. 1). The overhead projector image could be read by some pupils as an image of interconnect- edness. Weave can be thought of as a sheet of interconnectedness. The weave analogy focuses on interconnectedness whereas the analogy of 'wall' shows a balance between the notion of unit and interconnectedness. Pupil D we suggest has read the pattern created by the cell walls on the overhead projector as an example of interconnectedness, rather than the boundaries of isolated units.

It is interesting to note that Pupil D's use of analogy in her writing is reproduced from the teacher's speech. She writes of searching for 'a pattern like a honeycomb',

Wednesday 26th Nov
Looking at Cells

Step 1.

Peel off a bit of onion skin and put a drop of Iodine on it

Step 2.

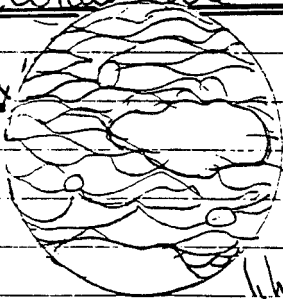
Place the onion skin on to a microscope slide and put a cover slip on top.

Step 3.

Put the slide on the microscope and get it into focus. Search for a pattern like a honey comb.

What We Saw

200x



✓ Diagram needs to be much larger. Did what you saw look like my 'diagram' in any way?

FIG. 5. Pupil D's text.

however, her image bears no relation to a honeycomb pattern and is based on her visual analogy of a wavy weave.

Conclusion

The pupils' construction of the entity 'cell' was a multimodal event, a process involving speech, action (in the form of experimentation) and image. The process of constructing the entity involved collating, selecting and adapting information from a range of modes. It also involved transforming/transducing information across modes (e.g. verbal analogy to visual analogy, experimentation into written report), each mode enabling information to be expressed and extended in specific ways (to say 'brick wall' and to draw 'brick wall' require different work), depending on the interests of the pupils.

In the pupils' use of analogy the teacher's conception of the cell was maintained and elaborated to incorporate the pupils' experiences and interests. The teacher's use of the 'building block' metaphor and a honeycomb arrangement as an analogy for the pattern of the cells is transformed by the pupils to a more familiar thing: a brick wall, a piece of cloth or the human skin. The teacher's interest in the aspects of regularity, uniformity and the organic within his analogy are maintained in the pupils' analogies. The attribution between positive and negative elements of an analogy is not a static classification, but a dynamic process of negotiation.

The visual entity 'cells' was not constructed in the lesson as such, but negotiated between the different worlds of scientific knowledge and the everyday. Where the scientific world consists of the pupils' knowledge of science and the envisaged world of the known, books and rules, the everyday world is made up of the pupils' perceptions, what they can see, say and imagine (e.g. through analogy). An example of pupils' negotiation between what is considered irrelevant in science and the teacher's rhetoric of 'seeing is believing' is the pupils' decisions to represent or to not represent an air bubble in their drawings. Where pupils' knowledge of what to ignore was limited, the negotiation was not possible and the 'seeing is believing' ideology elevated air bubbles to the status of cells: we are looking at cells, what we see is a cell. The pupils' conceptualisation of onion cells was more or less problematical depending on their understanding of air bubbles. So some pupils left them out, others represented them as 'irregularity', while others represented them as a part of the cell itself. These two worlds of reality worked together to produce a notion of scientific realism; a form of hyper-realism.

Focusing on the pupils' texts and their transformation of the teacher's communicative work (across modes, in terms of composition, genre and analogy) serves to emphasise the dynamic nature of the process of learning and the ways in which different pupils' interests influence this process. It also highlights how the visual and the written elements of a text can be used to attend to different aspects of meaning; to realise different functions.

We suggest that bringing a multimodal perspective to educational research has a number of advantages over perspectives which focus primarily on talk and writing. First, it enables research to focus on a rich range of resources, including talk, speech, image and action. This appears particularly important in the case of science education where action and image are often foregrounded in the classroom and highly valued within the curriculum. Second, a multimodal approach expands notions of 'work' (text and data) beyond speech and writing. We suggest that research which

focuses on learning and teaching as purely linguistic processes, fails to capture the full range of learning and teaching within the classroom and, in doing so, it negates the 'non-linguistic' work of teachers and pupils. In contrast, the interpretative work of making sense of diagrams, for instance, or, as discussed in this paper, the experience of looking at an entity through a microscope is brought into the arena of research by a multimodal perspective. Third, it highlights the active role of the teacher, not only in what he or she says, but in their actions, posture and movement.

A multimodal approach to the classroom also suggests new messages for the practice of science teaching. First, it highlights the need to attend consciously to all modes of communication, both in terms of the resources available for teachers and those made available to pupils (i.e. in the setting up of tasks). Second, it points to the need to develop an 'awareness' of how these modes are used in the science classroom (in the same way as educational research on language has made us more conscious of the use of language, pace and voice, as a resource for teaching). For example, asking what modes are used: are they used to attend to different aspects of a phenomena (e.g. using the visual as a filter for what to see and speech as instructions on 'how to see')? Third, a multimodal perspective also highlights the benefits of thinking about what mode may be 'best suited' to a task and the different cognitive and representational demands different modes place on pupils. Fourth, looking at learning and teaching as multimodal processes also requires thinking about the relations between modes in the construction of explanations, etc. For example, is the use of image, action and speech in a lesson producing conflicting messages or are they reinforcing each other? Much of this is implicit in the teaching of science but remains inaccessible at the level of 'intuition'. Our work suggests that there is a need for the 'work' of image, action and other modes to become more explicitly articulated, to be made available for reflection, refinement and improvement as teaching and learning resources.

We are not suggesting that the linguistic realisation of meanings is no longer important, we are, however, suggesting that the *visual realisation of meaning is important*. Learning can no longer usefully be considered a purely linguistic accomplishment. Within this multimodal environment, social semiotics with its emphasis on the many modes we use for representing and communicating and its insistence that signs come about as the reflection of the interest of their makers provides a framework for rethinking learning, for looking in detail at what pupils 'do'. It enables us to approach pupils' texts as one kind of evidence of their interests. This way of thinking about learning enables us to acknowledge the agency, interests and transformative work of pupils in learning. It also enables teachers to reflect productively on the effects of their teaching and on their responses to the pupils' interests.

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NOTE

- [1] This paper draws on the findings from an ESRC funded research project entitled 'The rhetoric of the science classroom: a multimodal approach', C. Jewitt, G. Kress, J. Ogborn, and C. Tsatsarelis, Institute of Education, University of London.

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