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Materiality as an Aspect in Learning

Zusammenfassung
In diesem Text wird anhand von Beispielen gezeigt, wie ein sozial-semiotischer Ansatz zu multimodalen Schülertexten (Texte, die eine Vielfalt von Fähigkeiten, einschließlich der visuellen, materiellen und aktionistischen anregen bzw. diese den Sinnen zugänglich machen) eine Möglichkeit bietet, Lernvorgänge zu verstehen. Unsere These lautet, dass Lernen als ein transformativer Prozeß von Zeichenproduktion interpretiert werden kann. Im Besonderen legen wir nahe, dass das Material (die Benutzung von Rahmen, Form, Beschaffenheit und importierte Objekte) verstanden werden kann, als die Art und Weise, wie Schüler sich mit Wissen und Lernen auseinandersetzen. Um dies deutlich zu machen, konzentrieren wir uns auf die visuelle Repräsentation von Zellen in zwei Klassen 11-jährige Schülerinnen einer Londoner Mädchenschule. Unsere Argumentation lautet daher, dass die Breite der visuellen Kommunikation (Raum-Beziehungen, Materialbeschaffenheit etc.) eine Art und Weise des Ausdrucks von Bedeutung ermöglicht, die schwierig oder vielleicht unmöglich gewesen wäre über verbalen Ausdruck. Unsere These lautet daher, dass visuelle und linguistische Ausdrucksformen unterschiedliche Potentiale zur Produktion von Bedeutung beinhalten und in der Folge unterschiedliche Lernpotentiale.

Abstract
In this paper we exemplify how a social semiotic approach to pupils' multimodal texts (texts which draw on and make available to the senses a range of resources, including the visual, material, and actional) can provide a way into understanding learning. We suggest that learning can be seen as a transformative process of sign making. Specifically, we suggest that materiality (use of frame, shape, texture, colour, and imported objects) can be seen as one expression of how pupils engage with knowledge and learning. In order to demonstrate this we focus on year seven (11 year old) pupils' visual representations of cells in two science classrooms at a London girls school. We argue that the range of representational resources available within visual communication (spatial relations, materiality, etc.) enabled the expression of kinds of meaning which would have been difficult, or perhaps impossible, in language. We conclude that visual and linguistic modes of expression have different potentials for meaning making, and therefore different potentials for learning.

1 Introduction

In this paper we first set out our theoretical approach to learning. We then use two sets of examples of pupils' visual texts drawn from the science classroom in order to exemplify this approach: one set consists of pupils drawings of onion cells seen through a microscope, the other consists of pupils' three-dimensional models of a cell. We conclude by commenting on the particular learning potentials made available to pupils and teachers working within the visual mode and comment on how taking a multimodal approach to pupils' texts can 'open up' new aspects of learning to those involved in educational research.

2 Social semiotics

Our theoretical approach is developed from HALLIDAY's (1985) social semiotic account of language. The field of social semiotics is primarily concerned with human semiosis as an inherently social phenomenon (HODGE/KRESS 1988, p. 261). The conceptual framework of social semiotics was originally designed to account for how language is used. This account is based on the assumption that language has evolved to satisfy societal needs, and semiotic resources are organised to function with respect to these needs: in other words, language 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. 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 meaning functions are modelled as sets of features which represent the work which is required (the choices available) when encoding or decoding a discourse.

Social semiotics emerged from the work of classical semiotics (classical semiotics refers to the Prague and Paris Schools of semiotics), however, there are two important differences between these approaches which are crucial to highlight given our view of learning as a dynamic process of meaning making. These differences stem from the attention given to the role of human agency and social context in the construction of meaning in social semiotics. Firstly, we view signs as the product of a process of sign-making which arises out of (and are motivated by) the cultural, social and psychological history of the sign-maker, focused by the specific context in which the sign is produced. That is, we do not view signs as having 'meaning by decree' or 'intrinsic relationships' (KRESS/VAN LEEUWEN 1996, p. 7). Secondly, the methods differ in the line they draw between 'langue' and parole' (langue refers to language in its abstract form, e.g. the English language; parole refers to speech that occurs in the everyday). Whereas classical semiotics draws a clear distinction between langue and parole, social semiotics does not. KRESS and VAN LEEUWEN (1996, p. 8) view langue as an artefact of analysis which amalgamates the resources of many speakers and many contexts. We argue that what is crucial to understanding representations are the resources available to particular people in specific social contexts. Like HALLIDAY, we view signs as motivated rather than arbitrary. Our work is therefore oriented to the description of signs as resources for meaning making rather than a system of rules.

Recently, this approach has been elaborated to take account of modes and systems of making meaning other than language, including music/sound (see VAN LEEUWEN 1999), action (see MARTINEC 1996), visual communication (see O'TOOLE 1994; KRESS/VAN LEEUWEN 1996), and most recently work in the HALLIDAYan functional linguistics (see MARTIN 1998), and in social semiotics has increasingly viewed the social production of systems of signs and meanings as a 'multi-modal' phenomenon.

3 Multimodality

Previous educational research has focused primarily on linguistic resources (talk, reading, and writing), reflecting the dominant view of learning as primarily a linguistic accomplishment. In contrast we explore the full repertoire of meaning making resources which pupils and teachers bring to the classroom (actional, visual, and linguistic resources), and how these are 'organised' to make meaning; that is, we take a multimodal approach to classroom interaction (see KRESS/OGBORN/MARTINS 1998; KRESS et al, in press). A social theory of communication enables us to view language and literacy practices as resources for making social meanings in the world. Extending our view of communication from language to include other modes of meaning making (e.g. gesture, and visual communication) highlights the need to consider the ways in which these modes express social meanings. A central aspect of visual communication in the science classroom that interests us, and provides the focus for this paper, is pupils' use of imported objects, shape, texture, and colour in texts – the materiality of texts.

4 Materiality as a means and evidence of learning

The materiality of texts (their physical characteristics) in the classroom has rarely been attended to within educational research. Where attention to the physical characteristics of texts has been given, it has provided a link between the study of texts and the study of practices, giving insight into children's literacy practices (see ORMEROD/IVANIC, 1999). The visual, and linguistic resources pupils draw on to make meaning in the science classroom can be viewed as the cultural working of a medium. The medium is worked and shaped over time into regular forms of representations (e.g. grammar) and becomes the material (signifier) for meaning (sign). In this way these forms of representation reflect the material, cultural-historical functional specialisms of visual and linguistic modes of communication: that is, the material potentials of visual and linguistic resources have developed (been shaped) over time in ways which enable the realisation of particular meanings.

We suggest that the meanings of pupils' texts are bound up with the choices they make from a range of meaning making systems (writing, visual), a variety of available materials, and the decisions they make in combining these. Pupils are engaged in many complex decisions when selecting how to materially represent something. That is, form and meaning are interconnected, and motivated: form is meaning.

5 Sign making as a process of learning

Social semiotics informs our understanding of the process of learning as *a dynamic process of sign making*. We view the ensemble of the situated communicative actions of the teacher as contributing to the resources and constraints involved in pupils' production of texts in the science classroom. In this way, we treat the pupils' texts as ⓘsemiotic objects' (signs) mediating their responses to the communicative actions made available in the classroom, and expressive of their interests: one kind of evidence of what their thinking may have been like. That is, we see meaning-making as a motivated activity, in which the interest of the sign maker (in this case the teacher and the pupils) is expressed through his or her selection of apt and plausible signifiers for the expression of the sign in a given context (KRESS 1997). We are interested in how pupils transform these materials (the structural and content aspects of teacher's communication) through the selection, the adaptation of elements presented, and the introduction of new elements. In other words, we are interested in how pupils use the resources made available to them in the classroom, from the teacher and other sources (e.g. other lessons, the television, their experiences and interests outside of the school) to construct meaning: in this case the entity 'a cell'. This can, from a different perspective, be seen as the process of learning.

In order to get at the cognitive process of pupils' learning we focus on the ⓘoutcome' of this process (in the form of texts). We argue that pupils' texts can be viewed as one kind of evidence of the cognitive processes that they have engaged in, and the effect of the teacher's communication at that particular moment on individual pupils. In this way we analyse pupils' texts in terms of the consequences, possibilities and limitations of their representational choices, both in terms of mode, elements and arrangements.

Approaching sign making as inherently involved in the dynamic process of learning, a complex process in which teachers shape ideas to be learned through a plurality of communicative means (linguistic, visual – materiality and three-dimensional, and actional) in order to make these ideas appropriate and convincing to pupils, 're-opens' the question of why pupils' texts vary. Today, viewing the learning process as the transmission of knowledge from teacher to pupil is less dominant amongst educational practitioners and researchers. Despite this, the common response to differences between pupils' texts as an indication of pupils' failure to correctly read (or reproduce) the stable messages encoded in teacher's communications is underpinned by this conception of learning. We suggest that variation between pupils' texts can be seen as an expression of pupils' different interests. That is, pupils' texts can be read as their shaping of meaning with the resources available to them in a specific context. Specifically, the texture, colour, shape, size – in other words aspects of the materiality of a text reveals traces of the cognitive work involved in producing it.

In this way, a multimodal social semiotic approach to pupils' texts opens up the potential to see differences between pupils' texts not as markers of their individual aesthetic (whether expressed through visual or other material/sensory means) but as a serious expression of different interests: as a transformation of the teacher's signs themselves made in a wide range of modes and materials, into new signs.

6 Pupils' texts as transformations: new signs

In this section we discuss pupils' visual representations of an onion cell, and 3D models of a cell produced by year 7 pupils in a girls' school in London. The images (figures 1 to 3) were produced within a science lesson. The models (figures 4 to 7) were produced as science homework following an introductory lesson on cells. The question raised for us by both these visual texts was 'what do the models mean for learning'.

In both instances we analysed the pupils' texts as textual objects, signs of their interested activity, as a way to bridge texts and practices. We look at how the pupils' used and appropriated the resources made available to them (school science styles, conventions, analogy, and materiality) for their own meaning making purposes in order to express their interests. The page of the text book, OHP image, and work sheets offered as key resources by the teachers, can be read as signs 'cells' and the pupils' texts (images and models) can be seen as transformations of this sign – new signs. The pupils' texts are a transformation of the text book signs 'cell' at the level of elements, and on the level of mode.

At the level of mode the pupils' models transformed the sign 'a cell' as presented in the text book from a written and visual two-dimensional representation into predominantly visual three-dimensional representations. The shift from written-visual to the exclusive, or more dominant, use of visual mode in the texts realised different representational potentials. Representations which involve material, visual, and three-dimensions engage pupils in a range of decisions which a linguistic task does not. Linguistically it is enough to say, ①the cell has a cell membrane'. To draw a cell membrane in two-dimensions involves consideration of thickness of line, depth, size, colour, frame, position on page, angle of representation, representational orientation (abstract, naturalistic, scientific, sensory), and medium of representation. To construct a three-dimensional model of a cell membrane involves consideration of texture and shape, spatial relations, and so on. that are not possible (or practical) in a textbook. That is, linguistic, two-dimensional visual representations, and three-dimensional visual representations demanded different work from pupils.

The pupils' texts transformed the textbook sign 'cell' by selecting, adapting and transforming elements of the cell and transforming the relations between elements of the cell. Comparison within each of the two sets of the pupils' texts discussed in this paper shows that: Each text (sign)

- Was a transformation of the teachers' sign cell – each of which was different.
- Used different representational resources within the semiotic modes available to them to make the sign.
- Reflected the cognitive decisions involved in representing a cell as a two or three-dimensional sign.

Through our analysis we explored the models as expressions of learning in order to demonstrate that the transformative processes which the pupils engaged with (e.g. their selection of resources, their decisions in arranging the elements in relation to one another) required them to engage with kinds of thinking and learning which a purely linguistic task would not have required: that is to show that mode is itself a part of shaping knowledge and an aspect of the learning process.

7 Two-dimensional images of onion cells

The images discussed below were produced by pupils looking through a microscope at a piece of onion epidermis. Below we explore the pupils' drawings as visual ⓣtraces' of their learning in order to consider the decisions they engaged with in the visual representation of onion cells.

7.1 Text one

We suggest that the image in the text expresses the pupil's complex understanding of what a scientific text ⓣshould be'. The image is a conceptual representation of a generalisation of what was observed. The image draws on scientific codes of representation (e.g. the waving lines in the left section of the image, and the lack of depth of the image) to realise an abstracted account of cells. The drawing appears to be primarily concerned with the idea of regularity and sameness: a visual search for, and presentation of ⓣscientificness' as a generalised pattern of meaning. The distinctly different pattern of the air bubble (the circle on the left of the image) and the cells visually marks their difference (although the pupil thought the air bubble was a part of the cell rather than an irregularity).

Figure 1

As the pupil looked through the microscope in the lesson she said, "it looks like a brick wall". This analogy is apparent in her drawing. She transformed and applied the analogy of a brick wall suggested in the worksheet, and implied in the teacher's verbal analogy with building blocks, and reproduced it by analogy in a the visual mode. The analogy focused on the positive elements of regularity and uniformity of cells and embodies 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 everyday-ness, cells are everywhere.

The rectangular framing of the image of onion cells indicates that what is important is not a representation of the whole of what can be seen through the microscope, the 'eye's view', but a selection of what can be seen. The frame of the image is abstracted from what was seen, that is the aperture of the microscope lens is not represented: the image is of a generalised section of the cells. The pupil's decision to use of a rectangular frame offers a different type of image, a different reality view, where the process by which the image has been made (the microscope) which provided a filter between the pupils' eyes and reality, has been 'left out'. Within the visual abstraction/generalisation of the cell it is perhaps interesting that she represented the air bubble on the left of the image that is that the empirical is read as reality. Within the same image the shading, use of colour (a pale green-yellow wash), and the level of detail represented in the image is suggestive of a naturalistic account. The combination of scientific and naturalistic codes in the image expresses the complexity of entering a new school genre and the relatively new concept of 'scientificness' for pupils in year seven.

7.2 Text Two

This text was produced by a pupil working in a pair with the above pupil, they looked at the same piece of onion skin, through the same microscope, over the same time period. The texts they produced are strikingly different. Why? For us the answer to this question is not one of drawing skills, it is instead an expression of the their different interests which mediated the emergence of different expressions of 'scientificness'. We suggest that this image can be seen as an attempt to realise 'scientificness' through the integration of the visual and the written elements in the text. That is, 'scientificness' is not fully realised visually or linguistically, but created through an interplay of the visual and the linguistic.

The image in this text provides a more naturalistic representation of cells: the air bubble and the aperture of the microscope lens are both represented (hand drawn circle), the yellow colour of the onion is included, the boundaries between air bubble and cell are not exaggerated (as in the previous image), and the organic line of the cell walls has not been abstracted. Her image is most like the teacher's metaphor of a honeycomb. The circular frame of the image is a convention used to encode the experience of seeing through a microscope. The circular frame embodies a sense of the experience of seeing through a microscope – it is not what is seen by the pupil (the image just fades at the edges). The image makes the equipment, the microscope, a part of the representation. This is not an image of a cell, but an image of a cell through a microscope. Here she uses frame to imbue 'scientificness' through the visual reference to the equipment of science: she draws on empirical realism rather than scientific conventions to realize 'being scientific'.

Figure 2

The boundary between the image and the writing in the text is less distinct than in the other texts discussed here. The writing and image are integrated under one title and subtitle: "looking at atonton cells" and "what I did:". She has written around the drawing so that the image provides a visual definition of the word to come "cells" and the 'evidence' of her statement "we could see the cells clearly". In other words, the meaning of the drawing is given by its intimate relationship with the writing: the integration of the story of what she did and the evidence of what she saw creates the 'scientificness' of the text – in the form of a visual definition.

7.3 Text Three

The visual element of this text is perhaps the most personal and least scientific. The image lacks colour and possesses a flatness both of which are suggestive of a abstract representation – moving more toward scientific code than a naturalistic one. The image has a circular frame which was tentatively drawn with a compass –which is itself suggestive of a tension between the certainty of a mechanically produced circle and the hesitancy of the maker. The circular frame of the image is a convention generally used to encode the

experience of seeing through a microscope making the equipment, the microscope, a part of the representation. Where in the previous text the circular framing device imbued 'scientificness' through a visual reference to the equipment of science we suggest that here it combines with the pattern created by the organic flow of the lines in the image to suggest 'the experience of looking'. That is the image realises a sensory or aesthetic code focusing on the emotion and affect of the event rather than a scientific code.

The image realises the pupil's involvement and excitement. The interest in the sensory is carried through in her use of the analogy of *"a wavy weave – in and out of each other in our microscopes"*. The image is represented beneath the title "what we saw" and the title for the writing is headed "looking at cells". These titles suggest that the agency involved in the visual experience of looking at the cells is different than the agency involved in making them visible. Through the writing the pupil transformed her experience of doing the experiment into a generalised set of actions, whilst through her image she asserts her individual experience of seeing the cells. The image is partially integrated with the title "What We saw": the top of the image is inserted between "What [top of image] We saw". In this way the image provides a visual result or 'evidence' of the experience described in the writing.

Figure 3

7.4 Summary

Our analysis shows that the pupils texts vary significantly and suggest that each pupil imported different elements from the teacher's instructions, talk, the worksheets, and their experience of the experiment. The pupils used different orientations of representation (scientific – abstract, naturalistic, and sensory-aesthetic); different frames (circular, or rectangular); they used colour and shade in different ways; and created different relationships between the visual and written elements of their texts. In short, the pupils responded differently to the rules of 'proper' scientific drawing included in the instructions of the teacher and implicit in the models of texts they were provided with. The pupils were all involved in the serious task of producing a text appropriate to a science lesson, and each found different ways of realising 'scientificness' in their texts.

8 Three-dimensional model of a cell

Here we focus on four models of a cell produced by year seven pupils as science homework. We discuss three aspects of meaning making (decisions and choices) made possible by the shift from a two-dimensional to a three-dimensional visual representation of a cell: texture, visibility, and movement of elements.

8.1 Texture

The pupils used materials with different textures and colours to make their models of a cell. The pupils made selections from materials available to them (sometimes involving substantial negotiations with parents about the materials). Here we argue that the pupils' choice of texture and shape demanded thinking and decision making in ways which a purely linguistic approach would not have.

In the text book the plant cell wall was represented linguistically as a 'rigid (firm) coating which helps the plant keep shape' and visually by a thick black line. Each of the models (figures 4 to 7) used different thicknesses of cardboard, plastic, and paper to represent the cell wall. These materials were used to create a textual transformation of the wall as firm, and smooth. In models 1 and 2 (figures 4 and 5) a cardboard box represented the cell wall, in model 1 it was covered with paper and painted, the paint added a powdery smoothness. The cell wall in model 3 (figure 6) was made from papier mache over a plastic box placed on a polystyrene pizza base, the papier mache was painted and covered with sellotape to give a smooth varnished effect. The representations of the cell walls were raised in shape to enclose the elements of the cell reflecting the common function of a wall – to keep things in and/or to keep things out. In the case of model 3, the pupil's use of colour (pale yellow), shape (circle) and texture (smooth, varnished) suggest a shell analogy. The design of the cell walls captured the need to *look into the cell* to see the components. In model 4 (Figure 7) the pupil used a section of a thick oval cardboard tube to represent the cell wall. This model represented a more abstracted view of a cell and a different notion of containment. In Model 3 (figure 6) the pupil used a circular shape to represent the outside of the cell (the wall) and a rectangular shape to represent the inner arrangement of elements. In this way she marked a clear distinction between inner and

outer, which was further marked by her use of different colours to mark outer (yellow) and inner (green). The pupils different use of shape and texture visually expressed notions of ①containment', transformed the 2D representation in the text book into a 3D representation, and echoed Hooke's metaphor of cell-wall.

The nucleus was described in the text book and by the pupils as 'the control centre' of the cell. The importance of the nucleus signalled in this analogy is, we suggest signalled in pupils use of texture and colour. In Model 1 (figure 4) the structure of the nucleus is complex: it is constructed from a pink bath sponge (cut into a circle) covered with red tissue paper placed in a circle cut out from the raised base of the model. The pupils' used the sponge to make a textural analogy between the nucleus as control centre and the brain (as sponge-like in popular analogies of absorbing knowledge). The red tissue paper intensified the colour of the pink sponge – the increased saturation signified attention. Representing the nucleus as 'bouncy', spongy, and red, the pupils conferred it the role of brain: confirming its centrality in the model. The solid heaviness of the stone used to represent the nucleus in Model 2 (figure 5), its movement, and the sound of its movement as it dragged or fell across the box of the model drew attention to and highlighted the nucleus in a way that other elements were not. The size and colour (black) of the nucleus in Model 3 (figure 6) served to indicate its salience. In model 4 (figure 7), the nucleus was represented as 'control centre' of the cell through the centrality of the arrangement of the elements within the oval cell wall. The tension of the string holding the elements together, literally realised the central 'controlled' meaning function of the nucleus. Through texture, shape, heaviness, and arrangement the pupils visually and physically expressed the central role of the nucleus within their models of a cell.

Figure 4

Figure 5

Figure 6

Figure 7

The vacuole was represented in the text book as a lagoon shaped space, and represented through a range of materials in the models. In Model 1 (figure 4) the vacuole was represented by a water bottle. In Model 2 (figure 5) it appeared as brown pencil lines on the base of the cardboard box. In model 3 (figure 6) a curved shape made of newspaper, covered with paper and coloured in black and yellow lines, was used to represent the vacuole. Model 4 (figure 7) used a thick bit of rubbery plastic – with a powdery surface to represent the vacuole. Each of these textures refers to an aspect of the expression of liquidity: employing materials in the most apt and plausible way to represent the pupils' interest. Model 1 used water as a 'direct representation' of the movement of liquid. The whole arrangement of the elements in the inner base of model 2 were reminiscent of an aesthetic impression of a pond scene (the cell in the book is a pond weed cell), the brown pencillines are like a representation of the ripples in water. Model 3 used shape to represent water – stored water as a lagoon. Model 4 used the thick rubber as an analogy for 'jelly-like'. That is the pupils were involved in the work of thinking about the qualities of 'sap' and how best to represent them with the resources available to them.
In selecting a material the pupils made decisions which reflected or extended their understanding of a cell. In short, the pupils' selections of texture and shape were motivated, not arbitrary: the material form and content of their signs wove together to make meaning.

8.2 Imported objects

Some of the pupils imported a range of 'ready-formed objects' (pre-existing signs) into their models.

The pupil who made model 2 chose to represent the nucleus with a grey-green stone. Her use of a 'natural' organic object brought with it traces of the context for the existence of the cell (displayed as a pond weed cell). The hard, round, 3D stone contrasts with the flatness of the rest of the model – making the stone salient. The stone moved as the box was moved, drawing attention to it (and what it represents) through movement and sound. The solid-heaviness of the stone produced a slow, controllable movement – the choice of a stone as compared with a marble, assured the stability of the function of control centre: as 'ordered monitoring'. The organic nature of the stone, its salience, and its potential movement in the box produced its centrality to the model.

Cling-film was used by several pupils to represent the cell-membrane in their models. It imported meanings of barrier, protection, and 'sterile' environments: echoing the pupils' understandings of the membrane as 'stopping germs and things coming in'. Here, the cling film served as a textual analogy (flimsy) and a functional analogy (barrier). In another model (not shown here) a pupil used white sugar cubes and small white buttons to represent the vacuole, and green sweets wrapped in sweet wrappers to represent the chloroplasts. Here we suggest that the imported objects indicated 'food' – and 'stored food'.

The representational potentials of culturally-shaped semiotic objects (pre-existing signs) were purposefully exploited in the models by the pupils: both in terms of their materiality, and the social meanings which they import, express. Cling film, water bottles, stones, sweets, and other semiotic objects have the potential to extend the representation of a cell from a material-physical analogy to a social analogy. In this way semiotic objects were used to express and extend pupils' understanding through material and social analogy.

8.3 Visibility: absence and presence

A visual representation, like all representations, is always a partial representation: more could have been shown, or less, or quite other things. Here we focus on how visibility, firstly in terms of *what* was made visible (what was represented/absent) and secondly, *how* it was made visible, can be seen as a meaning making resource which informed pupils learning.

The majority of the pupils represented all the parts of the cell named in the text book in their model (the cell wall, the cell membrane, vacuole, chloroplasts, cytoplasm, and nucleus). A few models did not represent all these elements, for example, in one model (Not shown here) the pupil used a hole to represent the nucleus. The model consisted of a cube made of white paper with a piece of paper inside the cube. Two holes at the centre of the front and back panels of the model revealed the inner section of the model, a sheet of paper with a pencil drawing of a scale-pattern. The hole had an essential role in enabling the viewer to see 'inside' the model-cell. Through its 'absence' the model emphasised the importance of the nucleus. The pupil did not represent the chloroplasts, cytoplasm, or vacuole, as separate elements in her model, rather these elements were re-

presented by the scale-pattern. The pupil transformed (amalgamated) each entity into a new sign – 'inside cell' and in doing so presented the cell as three elements: outside, 'nucleus as mediator', and inside. We suggest that the absence and presence of parts represented in the pupils models is one kind of evidence of what they considered to be significant in their representation of a cell.

The models varied in the degree to which elements were presented as immediately visible or 'to be revealed' (see Table 1).

Table 1: Visibility of elements in the models

	Model 1	Model 2	Model 3	Model 4
Visibility	partial (sill)	lid -> revealed	lid with a window -> revealed	immediately visible

The use of labels in Model 1 presented a cell as something which has to be looked into (from above) in order to see its elements. Models 2 and 3 (figures 5 and 6) presented a cell as something which is revealed: in the case of model 2 the lid of the box 'the outer cell wall' needed to be removed; in Model 3 the absence of papier mache on the plastic box lid created a 'window' through which to glimpse the inside of the model. In contrast Model 4 (figure 7) represented a 3D cross section of a cell, presenting the cell as an immediately visible phenomena.

The ways in which pupils constructed visibility in their models served to position the viewer in relation to the model. Model 1 positioned the viewer as an observer 'outside of the cell' looking in. Models 2 and 3 encoded the potential of science to look within, to go deeper. The creation of a window in the lid of Model 3 went further – as an expression of the experience of looking at a cell through a microscope. Model 4 placed the viewer immediately 'inside' the cell: rather than imbuing the experience of '*how* to look', it presented the model maker and the viewer as *involved in the scientific endeavour of looking*. The different ways in which elements of the cell were made visible encoded the model maker's and the viewers' relationship to knowledge, and science, as a range of different experiences.

8.4 Movement of elements

The transformation of the sign cell from the text book to the pupils' models of a cell enabled the potential for movement. In Models 1 (figure 4) and 3 (figure 6) movement was restricted to the movement of the water within the bottle, and the bounce of sponge – the elements themselves were fixed within the model. There was more potential for movement in models 2 and 4. The stone in model 2 (figure 5) was not fixed, it could move and be removed. The movement of the stone created a strong contrast within the otherwise still model, enabling different arrangements of the relationship between the nucleus and the other elements of the model, but fixing the other parts in their spatial relations. Model 4 (figure 7) incorporated the most movement: the whole model rolled; as the model rolled the plastic 'vacuole' and white sponge pieces 'wobbled' slightly changing the shape of the model, that is the elements of the model stayed in the same relation to one another but they shifted and moved slightly. This movement imbued organic, and living qualities on the cell. The 'fixidness' of the models carried within it the work of decision about where one element is in relation to another element: it conveys certainty. In the case of model 2 the movement of the 'nucleus' represented both an interpretation of what it means to 'be

a control centre' (i.e. to survey and monitor) and an expression of ambiguity of relations between elements – where is the nucleus in relation to the chloroplasts? In short, 'fixidness' expressed certainty on the part of the model maker, movement expressed the potential for uncertainty on the part of the viewer – both can be seen as further traces of decision making and cognitive work on the part of the model maker.

9 Conclusion

Comparison of the pupils' images and models of a cell showed that each can be seen as the product of interested activity, each one a unique transformation of the text book sign cell, drawing on different representational resources (but socially shaped), and reflecting the cognitive decisions involved in representing a cell as a three-dimensional sign. That is, the pupils' texts are an expression of learning as a transformative processes which required the pupils to engage with thinking and learning which a purely linguistic task would not have. Our analysis of these texts demonstrates that tasks which involve the visual promote learning through engaging pupils in questions and a range of decisions which a purely linguistic task does not. That is, they demanded different work from the pupils. The decisions required to represent a cell as a visual entity differ from those required by purely linguistic approach in three key ways.

(i) The spatial dimensions of the visual mode demanded consideration of the relationships between the different elements in a more detailed way than the linguistic mode. Further, the shift from two-dimensional to three dimensional representation opened up different potentials for the representation of relationships between elements through the possibility of layering, representations in depth, texture, and the potential to import pre-existing objects.

(ii) The representational potentials of the visual mode (i.e. texture, shape, colour) required the pupils to think about each of the elements in these terms. In this way the visual mode demanded that pupils engage with the functions and qualities of each element in a more considered way in order to decide how to best represent the entity a cell. For example, not just having to name a part but to visually represent it required consideration of shape, size, colour, and texture which linguistically would not have been required.

(iii) The visual mode raised a series of questions and decisions regarding how to represent an expression of 'scientificness' using visual resources which differed from the resources made available linguistically (e.g. the question of what looks 'real' – scientific conventions such as simplicity and abstraction, and use of colour).

We suggest that the selection of communicative mode shapes meaning: in other words, the 'translation' of meaning between modes (for example, the two-dimensional visual and linguistic modes of the teacher's sign 'cell' to the three-dimensional visual mode of the pupils signs of 'cell') can be seen as a transformation of meaning. Our analysis of the pupils' texts has shown how materiality can be a form of meaning making in the science classroom – materiality can be seen as an expression, or a 'trace' of pupils' engagement with learning. Focusing on materiality (line, texture, shape, and colour) enabled us to explore a range of aspects of learning:

(i) The analogies pupils used to construct the entity cell, the features and themes which appeared salient (e.g. containment, and relationships between inner and outer).

(ii) How pupils constructed differences and similarities between elements of the cell and how in doing so the pupils imbued them with different qualities and functions.

(iii) Pupils' understanding of the function of the elements.

(iv) Pupils' representations of concepts (e.g. concepts such as control represented as ⦶brain'), what they considered visually important, and the different ways they expressed this (e.g. through size, colour, shape, centrality).

The application of a social semiotic approach to the pupils' text and models of cells demonstrated that visual and actional communication is more than illustrative, or a question of encouraging pupil involvement as is often assumed. Different modes of communication provide pupils and teachers with different dimensions for meaning making. Images have different representational possibilities than words. The visual engaged pupils in work, thinking, decisions – in other words, learning – in different ways than writing and speaking. In short, a social semiotic approach offers a way into understanding the learning potential of communication beyond language and further access to the range of interests and resources pupils bring to the learning process.

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