7 Materiality as an expression of learning

Introduction

In this chapter we focus on four three-dimensional models of a plant cell produced by Year 7 students in a girls' school in London. The models (Figures 7.2 to 7.5) were produced as homework following an introductory lesson on cells. The students were given a week to make them. The question raised for us (and the teacher) by these models was what the models mean for learning.

Transformations: new signs

We analyse the students' models of a cell as textual objects, signs of their interested activity and as a way to bridge multimodal texts and practices. We look at how the students used and appropriated the resources made available to them (school science styles, conventions, analogy and metaphor, and materiality) for their own meaning-making purposes in order to express their interests.

The page of the textbook (Figure 7.1) was offered as a key resource by the teacher. It can be read as the authoritative sign 'cells', the knowledge at issue in its canonical form. The students' models can then be seen as transformations of this sign and as new signs. In the textbook two types of cell were represented, a cheek cell and a pond weed cell. For both representations, image was the foregrounded mode in the form of a photograph and a diagram, with writing used for a variety of purposes ranging from label to paragraph. The students' models are a transformation of the textbook sign 'cell' on two levels: that of mode and that of elements/content.

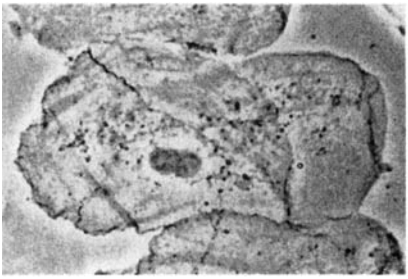
At the level of mode the students' models transformed the sign 'cell' as presented in the textbook from a written and visual two-dimensional representation into a predominantly visual three-dimensional representation. This shift brought different representational potentials. For example, in the models the students used texture and shape in ways that are not possible (or practical) in a textbook. Water

6.1 Cells

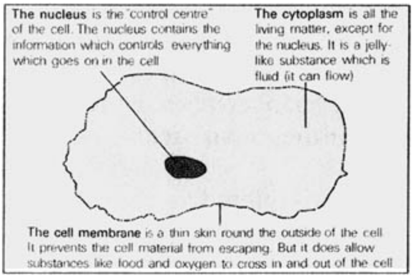
Starting-off

Before the photographs of the cells shown below were taken, a dye was put on the cells. This helps to show up the different parts of each cell. The photographs were then taken with a camera fitted to a microscope:

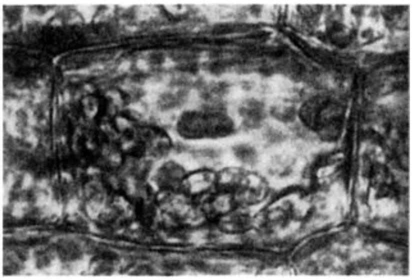
Cheek cell



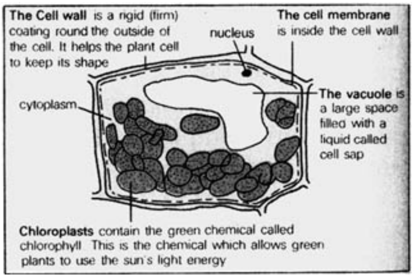
This is a photo of a cheek cell. The inside of your cheek is made up of many of these cells. In fact, your whole body is made up of millions and millions of tiny living cells joined together.
A diagram to help you see the main parts of the cheek cell is given below:



Pond weed cell



This is a photo of a cell from pond weed. The weed is made up of millions of tiny living cells, too.
A diagram to help you see the main parts of the pond weed cell is given below:



1 Why is the nucleus called the 'control centre' of the cell? ▲
2 What is the cytoplasm? What is it like? ▲
3 What is a cell vacuole? ▲
4 a) What do chloroplasts contain? ▲
  b) Why is this important? (Look at page 27 if you need help!)
5 Pick out the three parts which are found both in the cheek cell and in the pond weed cell (and in most other cells, too!).
6 **Try to find out:** when cells were discovered, and by whom.

Did you know?
- The cell membrane is only 0.000 01 mm thick.
- Animal cells don't have chloroplasts. They don't have cell walls either.

Figure 7.1 *Textbook page on cells (Alan Frasier and Ian Gilchrist,* Starting Science, *Book 1, Oxford University Press, 1996).* (Reproduced by permission of Oxford University Press) was used to represent the liquid in the vacuole, and a piece of sponge to represent the nucleus.

The expansion from the affordances of the two-dimensional page to those of a three-dimensional model made available different potentials for representing the elements and the relations between them. The three-dimensional models afforded the potential for more complex spatial arrangements between the elements than the textbook image (e.g. layering, and depth). In school science, cells are commonly interpreted by students as flat, since this is how they appear through a microscope. The models overcame this common interpretation of cells by presenting the space occupied by the cell as three-dimensional.

The students' models transformed the textbook sign by selecting, adapting and transforming elements of the visually and verbally represented cell, and transforming the relations between elements of the cell. The students transformed the spatial arrangement of the elements and the colour of some of them to make them more salient and to bring them into prominence.

I:	So is your model like a model of the drawing?
S1:	Well this cytoplasm went down like that and the nucleus was a really round circle in the middle and the vacuole was up here, so we changed it round.
S2:	And we didn't put the cytoplasm where it was in the book.
S1:	It isn't really the same as in the book.
I:	Right.
S2:	But we did take ideas from the book.
S1:	And, erm, in the book the nucleus was black.
S2:	So we thought we'd do it red.

In the textbook the two types of cell were presented as visually distinct via the compositional means of the page – the animal cell on the left, the plant cell on the right and the use of different colours to represent each cell type (blue for animal cell and green and yellow for plant cell). Some of the students merged elements from these two cell types to create a model of a new generalized sign 'cell'. Comparison of the students' models of a cell shows that each model/sign:

(1) was a transformation of the textbook sign 'cell'.
(2) used different representational resources in the semiotic modes available to the students to make the sign.
(3) reflected the cognitive decisions involved in representing a cell as a three-dimensional sign.

In our analysis here we explore the models as expressions of learning in order to demonstrate that the transformative processes in which the students engaged (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.

Reality in the science classroom

The criteria for the visual representation of truth are established by different social groups for the contexts in which they interact. These criteria, developed out of the central values, beliefs and social needs of these groups, act as relatively reliable guides to the truth or factuality of messages (Hodge and Kress, 1988; Kress and van Leeuwen, 1996). The students who made the models discussed in this chapter expressed the need for their models to relate to the 'real thing', to focus on and signal the criterial aspects of a cell, and to communicate meaning about the cell in particular ways. In the making of their models the students were engaged in the complex task of abstracting features of the entity 'cell' and presenting the abstraction as a likeness to the real thing. In part the students achieved this through their selection and arrangement of materials and imported objects – one part of their transformative action. In other words, texture, shape and colour were used as signifiers

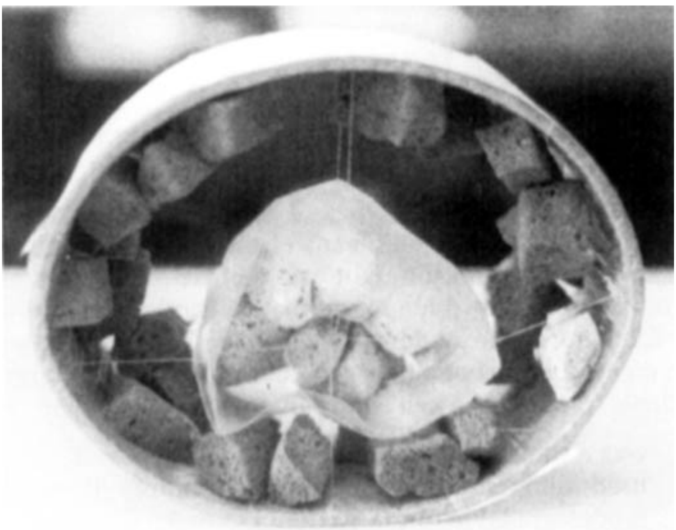


Figure 7.2 *Model 1 of a cell*

S2:	I like Stacey's [Figure 7.2] because it doesn't look quite the same, it's different actually when you hold it up to the light it looks like real.
I:	What do you mean? What looks real about it?
S2:	Well it looks ...
S3:	It's not, like, symmetrical like a lot of ours.
S2:	Hers looks, I don't know, like it's not planned and stuff.
S1:	It's sort of like it's natural.
S3:	It isn't put together and it's like really good.
I:	When you say it doesn't look planned like yours, it looks natural, tell me a bit what you mean.
S2:	Erm, I mean like, ... say it, erm, like ... symmetrical and things are exactly the same, but hers is like different and ... like erm, it's like, it's like, it's just like, like it's not planned or anything ... like everything is different.
I:	Yeah.
S1:	She has her own ideas, like we looked in a book and we thought, oh this must be like this, and oh the vacuole must be like this, whereas she thought, oh well let's, I think I'm not going to be like the rest, I'm going to change it and be different.
S2:	Like ... she put the string through the sponge so it's quite different, 'cos we've all like tried to get it exactly the same as we saw in the books and that.
S1:	She painted it green and she's just left hers quite simply and that.

of meaning – a range of resources which were selected and arranged to create meanings of truth, fact, certainty and credibility. What the students considered 'real' was informed by the framing of the task within science education. We asked the students what they liked about each other's models and it was clear that 'reality' was a central attribute for many of them. Here are two representative comments from that background.

In the context of science education, these students' sense of the characteristics of a visual representation of 'real' (and 'natural') appears to focus on two criteria: first, an absence of traces of the work involved in making the model (lack of planning and symmetry perceived as spontaneity, and therefore close to 'natural'), that is, an absence of the modeller guaranteeing absence of interference. Second, simplicity which belies the hard work involved in knowing what to leave out and what to put in, that is, how to abstract rather than simplify an object. In both cases human work is regarded as falsifying, as culture changing nature. We suggest that in an art classroom their sense of representations of reality would differ, perhaps focusing on a realism that stressed a likeness to nature. Making a model in art and in science both require labour, but the type of labour is different and the degree to which this labour is shown or allowed to be visible differs. Art is seen as showing the world as it is, science is seen as showing the world as it is known. In short, art is fact and science is interpretation:

the reverse of the common-sense belief. The process of producing 'scientific' representations appeared to us to be about the students' process of learning what to see and the transition between looking from within the frame of naturalistic reality to seeing with the frame of scientific reality – a hyperreality that gives visual form to things not usually seen. This transition is the process of negotiation and selection by students of what it is important to them to include and to make visible in their representations.

Texture, shape and colour

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

In the textbook the cell wall was represented linguistically as a 'rigid (firm) coating [which] helps the plant cell to keep its shape' and visually by a thick black line. Each of the models 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 2 and 3 (Figures 7.3 and 7.4) a

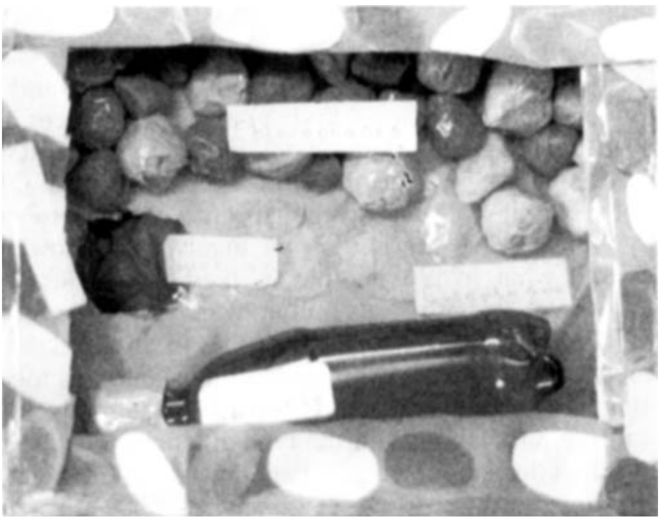


Figure 7.3 *Model 2 of a cell*

Figure 7.4 *Model 3 of a cell*

cardboard box represented the cell wall; in model 2 it was covered with paper and painted, the paint adding a powdery smoothness. The cell wall in model 4 (Figure 7.5) was made from papier-mâché over a plastic box placed on a polystyrene pizza base; the papier mâché was painted and covered with Sellotape to give a smooth varnished effect. The 'cell walls' were raised to enclose the elements of the cell, reflecting the common function of a wall. In the case of model 4, the student's use of colour (pale yellow), shape (circle) and texture (smooth, varnished) suggested a shell by analogy. Here the design of the cell walls captured the need to *look into the cell* to see the components. In model 1

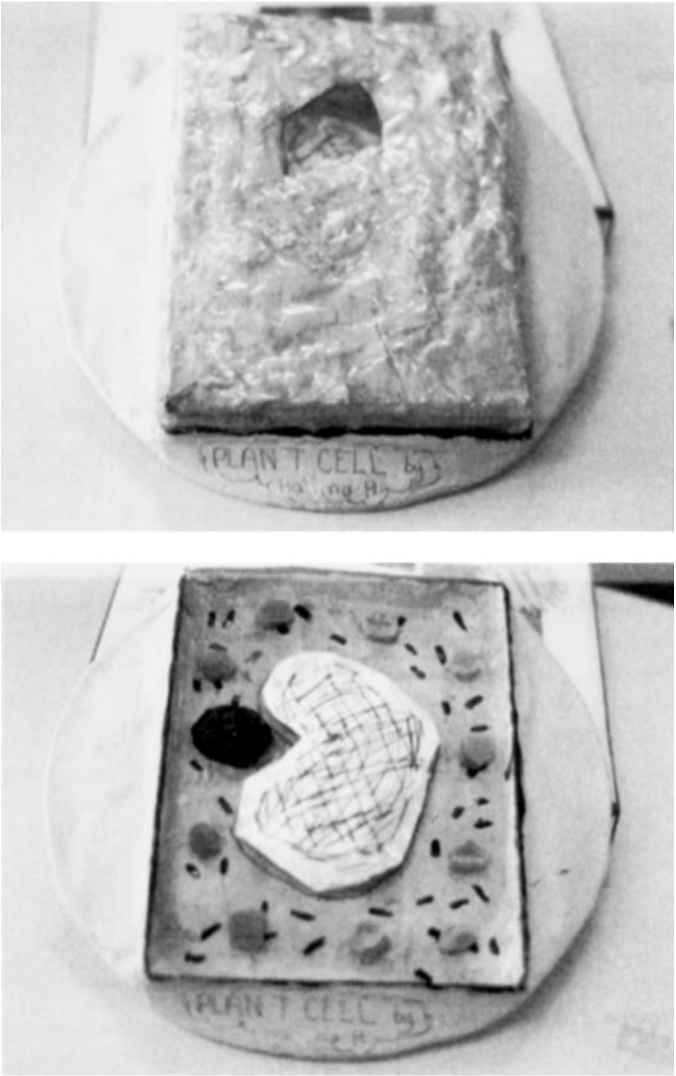


Figure 7.5 Model 4 of a cell

(Figure 7.2) the student 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 4 (Figure 7.5) the student used a circular shape to represent the outside of the cell 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). This student's different use of shape and texture visually expressed notions of containment, transformed the two-dimensional representation in the textbook into a three-dimensional one and echoed Hooke's metaphor of cell wall (Hooke, 1667).

As in the textbook diagram (Figure 7.1), the cell membrane in each model was represented as different to the cell wall. In the textbook diagram the bold line for the wall contrasted with the lighter broken line representing the membrane. In contrast to the hard smoothness of the cell walls in the models, the cell membrane was represented as flimsy, shiny, crinkly and thin. Here the use of texture embodied the meaning of lived delicacy. Model 2 (Figure 7.3) used tissue paper, models 1 and 3 (Figures 7.2 and 7.4) used clingfilm, and model 4 (Figure 7.5) used the thin edge of a plastic box. In model 2 the cell membrane was represented from an aerial view. Oval leaf or petal shapes made out of tissue paper were glued (making the paper more transparent) onto a thin paper overhang around the top edge of the box. These materials realized students' understanding of how thin and delicate cell membranes are. In models 1 and 3 the use of clingfilm, and to a lesser extent the use of plastic in model 4, drew on the everyday function of these materials to express the function of the cell membrane to protect. In another model (not shown here) a raised line of cardboard dashes represented the cell wall – a direct translation/transformation of the hesitancy of the line in the two-dimensional diagram. The students' choice of materials carried the meaning and function of delicacy in different ways and involved them in serious decisions around representation such as how to imbue specific qualities and meaning to a model cell through the affordances of materiality.

The nucleus was described in the textbook and by the students as the control centre of the cell. The importance of the nucleus signalled by this metaphor is represented in the use of texture and colour. In model 2 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 students had used the sponge to make a *textural* analogy between the nucleus as control centre and the brain (as *sponge-like*, in a popular analogy based on 'absorbing knowledge'). The red tissue paper intensified the colour of the pink sponge – the increased saturation used to signify salience. Representing the nucleus as bouncy, spongy and red, the students had conferred on it the role of 'brain', thus confirming its centrality in the model.

S1:	The nucleus is quite sort of like bouncy.
I:	Why are they bouncy?
S2:	I don't know.
S1:	Well first we put in, erm, this pinkish sponge that she had.
S2:	For scrubbing the body.
S1:	And she cut a bit out and put it in, and I go and then we both decided to put tissue paper to make it.
S2:	Because the sponge was bit dull.
S1:	Yeah.
S2:	The, erm, nucleus is the control centre of the cell.
I:	The control centre?
S2:	Yeah.
I:	What does that mean?
S1:	It's like the brain of the cell.
I:	OK. What does it control?
S1:	It just like controls.
S2:	Everything inside the cell.

In model 3 (Figure 7.4) the solid heaviness of the stone used to represent the nucleus, 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 did not. The size and colour (black) of the nucleus in model 4 (Figure 7.5) served to indicate its salience. In model 1 (Figure 7.2) the nucleus was represented as the 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 realized the central controlled meaning function of the nucleus. Through a variety of material means – texture, shape, heaviness and arrangement – the students visually and physically expressed the central role of the nucleus within their models.

The material realization of the chloroplasts in the models all reflected the students' sense of what the characteristics and the functions might be. The use of green in the models no doubt came from the textbook images of a pond weed cell but was transformed to a range of shades of green within a single model: possibly to show changing energy levels. The students' models transformed the shape of the chloroplasts in the diagram from the oval irregular shape to square chunks and petal shapes. The chloroplasts were represented as something 'wrapped', whether in tissue paper as in model 2 (Figure 7.1) or as sweet wrappers elsewhere. The function of the chloroplasts is to store the chemicals required for photosynthesis and the use of a wrapping appears to signify and imbue meanings of containment and storage while the texture of the material used in wrapping gave insight into what the students thought the texture and function of the 'skin' of the chloroplast might be.

Chloroplasts were also represented as leaf-like paper shapes painted shades of green as in model 3 (Figure 7.4). Here the use of texture and shape serves to highlight the organic result of the function of chloroplasts to keep leaves green. Additionally, they were represented as circular or square chunks of sponge painted green in models 1 and 4 (Figures 7.2 and 7.5). The students' decision to use sponge painted green appears to have been an attempt to draw on the analogy of sponge as container-absorber of greenness. The task engaged the students in new sign-making including the transformation of shape, colour and the introduction of texture to create visual representations of the function of the chloroplasts in a cell.

The vacuole was represented in the textbook as a lagoon-shaped space; in the models it was represented through a range of materials – in model 2 (Figure 7.3) by a plastic water bottle, in model 3 (Figure 7.4) by brown pencil lines on the base of the cardboard box. In model 4 (Figure 7.5) a curved shape made of newspaper, covered with paper and coloured in black and yellow lines, was used. Model 1 (Figure 7.2) 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 liquid, employing materials in the most apt and plausible way to represent the students' interest. Model 2 used water as a direct representation of the movement of liquid. The arrangement of the elements in the inner base of model 3 was reminiscent of an aesthetic impression of a pond scene while the brown pencil lines are like a representation of the ripples in water. Model 4 used shape to represent water – the stored water of the vacuole as a lagoon. Model 1 used the thick rubber as an analogy for being jelly-like. In each case the students had been involved in the serious work of thinking about the qualities of sap and how best to represent them with the resources available to them.

In summary, as Table 7.1 shows, the students' used a range of textures to represent the different elements of the cell.

Their decisions and selections in relation to texture, shape and colour expressed meanings which were further shaped by their incorporation and arrangement of these materials and shapes into their models. In selecting a material, the students made decisions which reflected or extended their understanding of a cell. In short, their selections of texture and shape were motivated, not arbitrary. The material form and content of their signs wove together to make meaning.

Table 7.1 *Students' textural representation of elements in their models of a cell*

Element	**Texture**			
	Model 1	**Model 2**	**Model 3**	**Model 4**
cell wall	smooth, firm	rigid, firm	solid, smooth, powdery and shiny	rigid, smooth
cell membrane	thin, transparent, papery	flimsy, stretchy, clear	thin, clear, shiny	flimsy, stretchy, clear
nucleus	spongy	hard, stone	hard, slight bounce	sponge
chloroplasts	wrapped, layered, soft on hard	flat paper, layered	sponge	sponge
vacuole	flexible water container	flat	hard, slight bounce	powdery, jelly-like

Imported objects

Some of the students imported a range of ready-formed objects as signifiers with specific histories into their models. In this section we discuss the already-shaped semiotic meanings of imported objects in four models, and the resonant yet transformed meanings of objects through their relocation in the models as a resource for meaning-making and learning.

The vacuole was represented in the textbook linguistically as 'a large space filled with a liquid called cell sap' and represented visually as a large white lagoon shape (see Figure 7.1). The students who made model 2 (Figure 7.3) represented the vacuole by a green water bottle filled with water with green ink in it. They explained their use of the ink as an attempt to thicken and dye the water green. In this way, their representation presents the vacuole as a container and the sap as both more viscous than water and as a green liquid. We suggest that their choice of a water bottle conveyed meaning by establishing the role of the vacuole in maintaining and storing resources (drinking water). In this context the function of the bottle is as storage and that of the sap is signalled as resource.

The student who made model 3 (Figure 7.4) chose to represent the nucleus with a grey-green stone. Her use of a natural physical object brought with it traces of the context for the existence of the cell. The hard, round stone contrasts with the flatness of the rest of the model. 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 physical nature of the stone, its salience and its potential movement in the box produced its centrality to the model and to what it represented.

Clingfilm was used by several students to represent the cell membrane. It imported meanings of barrier, protection and sterile environments, echoing the students' understandings of the membrane as 'stopping germs and things coming in'. Here, the clingfilm served as a textural analogy (flimsy) and as a functional analogy (barrier).

In another model (not shown here) a student 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 are purposefully exploited in the models by the students both in terms of their materiality and the social meanings which they import and express. These objects have the potential to extend the representation of a cell from a material-physical analogy to a social analogy to express and extend students' understanding through material and social analogy, linking them into the wider metaphoric systems of their cultures.

Visibility: absence and presence

A visual representation is always partial. Here we focus on how 'visibility' can be seen as a meaning-making resource which informed students' learning.

The majority of the students represented all the parts of the cell named in the textbook in their model (cell wall, cell membrane, vacuole, chloroplasts, cytoplasm and nucleus). A few models did not represent all these elements, for example one model represented the nucleus as a hole. 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 emphasized the importance of the nucleus. The student did not represent the chloroplasts, cytoplasm or vacuole as separate elements in her model, rather these elements were represented by the scale pattern. The student transformed each entity into a new sign and in so doing presented the cell as three elements: outside, nucleus as mediator, and inside. We suggest that the absence and presence of parts represented in the students' models is one kind of evidence of what they considered to be significant in their representation of a cell.

The photographic images and the accompanying text in the textbook signalled the microscopic process by which they were made visible. In addition, the arrangement of the diagrams directly below the photographic representations signalled them to be a product deriving from them. Their origin and process of production were made explicit in the arrangement of the page. For some students the shift from image to model signalled a need to carry over the encoded experience of seeing through the use of lids and of windows into the models. As shown in Table 7.2 below, the models varied in the degree to which elements were presented as immediately visible or as to be revealed.

Table 7.2 *Visibility of elements in the students' models of a cell*

	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 2 presented a cell as something which has to be looked into (from above) in order to see its elements. Models 3 and 4 (Figures 7.4 and 7.5) 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 4 the absence of papier-mâché on the plastic box lid created a window through which to glimpse the inside of the model. By contrast, model 1 (Figure 7.2) represented a three-dimensional cross-section of a cell, presenting it as an immediately visible phenomenon.

The ways in which students constructed visibility in their models served to position the viewer in relation to the model. Model 2 positioned the viewer as an observer outside of the cell looking in. Models 3 and 4 encoded the potential of science to look within, to go deeper. The creation of a window in the lid of model 4 went further as an expression of the experience of looking at a cell through a microscope. Model 1 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 thereby the viewer's) relationship to knowledge and science, as a range of different experiences.

Design

The different ways students chose to frame their cells (e.g. rectangular or circular frames), and their use of texture, shape and colour to realize salience have been discussed in the previous sections of this chapter. Here we focus on how the design of a text and the spatial arrangement of elements produces meaning (Kress, 2000b). The meanings of visual texts can be understood by attending to visual semiotic structures such as composition, the frame of an image and salience (Kress and van Leeuwen, 1996). We discuss two aspects of the students design: centrality and movement *vs.* fixity. Our aim is to be able to discuss the relationships between the elements represented in the students' models of a cell and learning.

Centrality

Centrality is a way of conferring importance on an element. In the textbook (Figure 7.1) the nucleus is represented at the centre of the photograph of the diagram of an animal cell, and at the top right in the representations of a pond weed cell. Some of the students used centrality to confer importance on particular elements (others used colour, size or texture). Model 2 (Figure 7.3) transformed the relationships between elements as shown in the textbook and used centrality to equalize the importance of different elements within the cell: the vacuole was made salient through its size (but it was not foregrounded through the use of colour – it blended in with the other green elements); the nucleus was made prominent through its bouncy texture and use of colour (red); the chloroplasts were made salient through sheer number and the amount of space they occupied. The central space in the model remained empty. This utilization of the central space was also apparent in model 3 (Figure 7.4) where the vacuole occupied the inner, rather than the central, space of the model – the area in which the nucleus could move. In both models centrality was used to create a harmonious symmetry in the relationships between the other parts and within the model as a whole. By contrast, in model 4 (Figure 7.5) the elements were arranged around a central composition to highlight the vacuole and to marginalize the chloroplasts. Centrality was perhaps most significant in the arrangement of the elements within model 1. Here the nucleus was represented as central, both literally and in terms of how the model is held together (through the tension of cotton string between the outer and inner elements of the model). The students drew on centrality as a representational resource for making different kinds of meanings to represent the relationships between elements within the cell as equal or as hierarchical.

Movement vs. fixed

The transformation of the sign 'cell' from the textbook to the students' models enabled the potential for movement. In models 2 (Figure 7.3) and 4 (Figure 7.5) movement was restrained 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 1 and 3. The stone in model 3 (Figure 7.4) 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 positions. Model 1 (Figure 7.2) incorporated the most movement. The whole model rolled and as it did so, 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 fixity of the models carried within it the work of decision about where one element is in relation to another element, and thereby conveyed certainty. In model 3 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 about relations between elements – where is the nucleus in relation to the chloroplasts? Fixity 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 traces of decision-making and cognitive work on the part of the model-maker.

Materiality and learning

Comparison of the models showed that they can be seen as the product of interested activity, each one a unique transformation of the textbook sign 'cell' drawing on different representational resources and reflecting the cognitive decisions involved in representing a cell as a three-dimensional sign. The models are an expression of *learning as a transformative process* which required the students to engage with thinking and learning in a way that a purely linguistic task would not have required. Linguistically it is enough to say 'the cell has a cell membrane'. To draw a cell membrane involves considerations of thickness of line, depth and medium. To construct a three-dimensional model of a cell membrane involves deciding what it looks like, what material can best represent it, where it is placed in relation to the cell wall, and so on. The construction of the models demanded different work from the students. Our analysis suggests that the decisions required to represent a cell as a visual, three-dimensional entity extended the students' learning well beyond that required by a purely writing-based approach in three key ways.

First, 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: the visual demands a commitment which the verbal does not. In addition, 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 and texture, and the potential to import pre-existing objects.

Second, the representational potentials of the visual mode (i.e. texture, shape, colour) required the students to think about each of the elements in these terms. In this way, the visual mode demanded that students engage with the functions and qualities of each element in a much more considered way in order to decide how to best represent the entity 'cell'. For example, having to physically represent a part, not just name it, required consideration of issues not present in a linguistically framed task, and issues around representation which would not have been required linguistically.

Third, the visual mode raised a series of questions and decisions regarding how to represent the expression of scientificness, in that the visual resources differed so profoundly 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).

Our analysis of the models has shown that materiality is a resource available for meaning-making in the science classroom. Materiality can be seen as an expression of students' learning. Focusing on texture, shape and colour enabled us to begin to explore a range of aspects of learning:

(a) The analogies students used to construct the entity 'cell', the features and themes that appeared salient (e.g. containment, and relationships between inner and outer).
(b) How students constructed differences and similarities between elements of the cell and how in doing so the students imbued them with different qualities and functions.
(c) Students' understanding of the function of the elements.

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

The shift from text and two-dimensional image to three-dimensional model engaged students in the transformative process of sign-making on the level of mode and on the level of element. We suggest that the selection of communicative mode shapes meaning, that is the 'translation' of meaning between modes has to be seen as simultaneously the transformation of meaning. The application of a social semiotic approach to the students' models of cells demonstrates that the visual and the actional as communication are more than merely illustrative, or a question of fostering student involvement and engagement. Different modes of communication provide different dimensions for meaning-making and this is true for the relations of all modes, action no less than writing. This approach *can* engage students in work, thinking and learning in ways which writing cannot. In short, a social semiotic approach offers a way into understanding the learning potentials of all modes of communication beyond language-as-speech or language-as-writing, and gives access to the range of interests and resources students bring to the learning process.